III. Water Conservation Standards and Guidelines for Multi-Family Residential; Commercial, Office, Institutional and Industrial Land Uses; and Residential Subdivisions with Less than Five Units

The water conservation information and methods in this chapter apply to the following uses and their corresponding zoning categories: R-2 Apartment Zone, M-H Mobile Home and Single Family Residential Zone, O-1 Office and Industrial Zone, C-N Neighborhood Commercial Zone, C-1 Neighborhood Commercial Zone, C-2 Community Commercial Zone, and C-LI Commercial/Light Industrial Zone, M-1 Light Industrial Zone, M-2 Heavy Manufacturing Zone, and special use permits for similar uses. The descriptions that follow mention some of the requirements for each zone. In most cases a grading & drainage plan prepared by a New Mexico licensed engineer is required. For a full listing see the Bernalillo County Zoning Code (Appendix A of the Bernalillo County Code of Ordinances).

Corresponding Zones:

R-2 Apartment Zone - Permits, in appropriate areas, higher density of population than in single-family zones and still maintains a residential environment.

a. Minimum lot area for developments other than townhouses shall be 8,000 square feet and the minimum lot width shall be 60 feet, provided community water and sewer services are made available.
b. For townhouses, the minimum lot area shall be 4,000 square feet and the minimum width shall be 24 feet, provided community water and sewer facilities are available.
c. If community utilities are not available, then the minimum lot size shall be three-quarters of an acre per dwelling unit.

M-H Mobile Home and Single-Family Residential Zone - Provides for development of subdivisions or groups of contiguous parcels of land having a minimum total area of five acres, with a mixture of mobile homes and single-family residences on individual lots.

a. Every lot shall have a minimum area of not less than three-quarters of an acre and a minimum lot width of 60 feet. Where community water and sewer services are available, the lot area may be decreased to 8,000 square feet if located in the Developing, Established or Central Urban Areas, or 14, 520 square feet if located in the Semi-Urban Area of the Albuquerque/Bernalillo County Comprehensive Plan.

O-1 Office and Industrial Zone - Provides sites suitable for office, service, and industrial uses.

a. No minimum lot area or lot width. See Appendix A, Zoning Section 12 of the Bernalillo County Code of Ordinances for setback, landscape and landscape buffer requirements.

C-N Neighborhood Commercial Zone - Provides for retail businesses and services serving primarily the residents of the neighborhood while minimizing any adverse effects on nearby residential development.

a. No minimum lot area or lot width. The gross building floor area maximum for one business shall not exceed 4,000 square feet. See Appendix A, Zoning Section 13 of the Bernalillo County Code of Ordinances for setback requirements.

C-1 Neighborhood Commercial Zone - Provides suitable sites for office, service, institutional, and limited commercial uses to satisfy the day-to-day needs of nearby residential areas while minimizing any adverse effects on nearby residential development.

a. No minimum lot area or lot width. See Appendix A, Zoning Section 14 of the Bernalillo County Code of Ordinances for setback, landscape and landscape buffer requirements.

C-2 Community Commercial Zone - Provides for appropriate community commercial uses.

a. No minimum lot area or lot width. See Appendix A, Zoning Section 15 of the Bernalillo County Code of Ordinances for setback, landscape and landscape buffer requirements.

C-LI Commercial/Light Industrial Zone - Provides for community commercial uses, light manufacturing, light fabricating, warehousing, and wholesale distribution with off-street loading and off-street parking for employees, and with ready access to arterial highways or railroads.

a. No minimum lot area or lot width. See Appendix A, Zoning Section 15.5 of the Bernalillo County Code of Ordinances for setback, landscape and landscape buffer requirements.

M-1 Light Industrial Zone - Provides for light manufacturing, light fabricating, warehousing, and wholesale distribution with off-street loading and off-street parking for employees, and with ready access to arterial highways or railroads.

a. No minimum lot area or lot width. See Appendix A, Zoning Section 16 of the Bernalillo County Code of Ordinances for setback, landscape and landscape buffer requirements.

M-2 Heavy Manufacturing Zone - Provides for industrial operations of all types except that certain potentially hazardous or nuisance-type industries as specified in Appendix A, Section 17, subsection B.2 are permitted only after public hearing and review to ensure protection of the public interest and surrounding property and persons.

a. No minimum lot area or lot width. See Appendix A, Zoning Section 17 of the Bernalillo County Code of Ordinances for setback, landscape and landscape buffer requirements.

A. Introduction

Landscape irrigation accounts for approximately 40% of the potable water used in Albuquerque, according to the Albuquerque Bernalillo County Water Utility Authority. As part of the County's water conservation efforts, Bernalillo County has enacted a Water Conservation Ordinance that requires inclusion of water conservation measures for new development, additions and remodels. Employing water conservation measures can save billions of gallons of our potable water supply. This chapter provides information and methods appropriate for water conservation on higher density residential, commercial, office and industrial sites.

Landscape Types

For the sake of simplicity, landscapes can be categorized as ornamental or functional. Ornamental landscapes exist mainly for aesthetic value and can be formal or informal, elaborate or simple. Functional landscapes have a primary purpose other than aesthetics and include uses such as athletic fields, playgrounds and agriculture. An additional method of classifying landscapes is by the design and the selection of plants. Using this method, the five landscape types listed below are commonly found in Bernalillo County.

- **Natural or Reclaimed Landscape -** This landscape type emphasizes protection of the native landscape and reclamation or restoration of disturbed areas with native or adapted plants. Re-contouring the land and correcting a disrupted watershed are required, and construction techniques and products specifically developed for restoration are commonly used. Mulches are generally applied only in connection with reseeding. Temporary irrigation may be used or plantings may rely solely on natural precipitation for sustenance.

- **Precipitation-Supported Landscape** - Also known as precip, precipitation-only, or rainwater supported, this landscape is extremely water conservative and uses native and adapted xeric plants, usually mulched with gravel or bark chips. Reclamation areas may also be included in this landscape type. It differs from the xeric landscape type in that it relies exclusively on natural precipitation to sustain the plants after they are established. Prior to establishment either natural precipitation or temporary irrigation may be utilized. If used, the irrigation system may be a mix of high efficiency spray and bubblers and/or drip irrigation.

- **Xeric Landscape** - The word "xeric" is derived from the Greek word "xeros", or dry, and a xeric landscape or "xeriscape" is a water-efficient, low maintenance landscape that is appropriate to the natural environment. Xeriscaping refers to using plants that have low water needs, but also to a site-specific approach to the landscaping plan. Xeriscapes typically use native or adapted drought-tolerant plants in beds mulched with gravel or bark chips but can also include areas of low-water-use turf and wildflowers. This landscape type is typically irrigated with bubblers, drip irrigation systems and high efficiency spray and can significantly reduce water use compared to a traditional high-water-use landscape.

- **Traditional/Xeric Mix Landscape** - This landscape mixes traditional high-water-use landscape with xeric planting areas. In this type of landscape the higher water uses such as grass, trees and shrub beds are typically concentrated in heavy use areas, while xeric landscape areas are located along perimeters and less used areas of the residence. It is typically irrigated with a mix of high efficiency spray and bubblers as well as drip irrigation. Shifting all or part of a landscape that consists of high-water-use plantings or turf areas to traditional/xeric or xeric landscape can reduce water use significantly, generally by one third to one half.

- **Agricultural Landscape Uses** - This landscape type is focused on agricultural or food-producing uses and can be part of any of the other types of landscapes. Agricultural landscapes normally require irrigation, but depending on plant or crop type, irrigation could be precipitation-only. Bubblers, drip systems or flood irrigation with conservancy water are commonly used for agricultural landscapes.

Shifting from a landscape that consists of high-water-use turf areas and high-to-moderate water use shrubs and trees to a xeric landscape, or a combination of traditional and xeric landscape can reduce consumptive water use by one third to one half. An integrated site design links the site's water, energy and aesthetic requirements with its available resources such as runoff, shade and vegetation. An integrated site design with xeriscaping not only saves water, but also respects the environment and region. Regardless of the style or level of complexity, the following basic steps apply when developing an integrated design to achieve water conservation.

Benefits of Xeric Landscapes

- Water savings: Using drought tolerant plants can reduce water consumption by 50% or more.
- Reduced maintenance: Reducing the amount of high-water-use plants and turf areas reduces the amount of time and money spent on fertilizing and mowing.
- Habitat creation: Provides a source of food and other necessities for birds, insects and animals.

B. Recommended Steps for Water-Conserving Site Design

Integrated site design uses a multidisciplinary approach to create a water-conserving site plan that matches requirements such as aesthetics and water conservation with the site's resources, such as runoff and existing topographic features. Integrated site design goals include retaining rainwater on site, minimizing disturbance of existing vegetation and soils, retaining existing topographic features and grading to the extent possible, and taking advantage of wind and solar patterns to increase heating and cooling efficiency. The process steps for developing an integrated site design are listed below.

1. **Involve a Multidisciplinary Team in Site Development.** Optimal site design, in terms of water efficiency and conservation as well as functionality and aesthetics, is best achieved with analysis and design inputs from a range of disciplines, including civil engineering, building and landscape architecture and developer and construction experts. Engaging representatives from the relevant disciplines at the outset of the design development process can help to achieve the best balance between site development cost and performance through design efficiencies. It is also preferable for the team leader to have a solid understanding of site drainage issues and water-harvesting techniques.

2. **Analyze the site**. A detailed analysis of the site's physical characteristics and conditions is the foundation for an integrated site design. The first step is creating a base plan or diagram of the site.

   In order to design a site to maximize water conservation, the interaction of three major factors that determine how water performs on a site must be analyzed: the quantity of runoff, the shape and steepness of the surface it runs over, and the type of material it is running over, such as vegetation or man-made materials. The site analysis plan should note characteristics including:
   - Topographic features such as slopes, depressions, high points and how they will impact the movement of water on the site. If available, a detailed contour map of the site can be useful. Consideration of the site's location relative to the slope of nearby properties is important to identify where water may be entering or exiting the site.
   - Stormwater drainage patterns, including where runoff from roofs and other impervious surfaces enter the landscape. Note areas such as natural depressions which present water harvesting opportunities. See additional information in the "Key Concepts of Water-Conserving Landscape Design" section below.
   - Locations of existing vegetation as well as vegetation type and condition. Non-native, unhealthy, invasive or otherwise undesirable plants to be removed (e.g. Russian olive, salt cedar, Siberian elm) should also be noted.
   - Locations of existing utilities.
   - Conditions, including locations of microclimates, seasonal wind patterns, wildlife corridors, and human traffic patterns.
   - Viewsheds to be preserved or screened.
   - Land use types of adjacent parcels.

3. **Assess the site soils and geology. A geotechnical assessment of the site will provide data regarding soil characteristics, compaction, bearing capacity and qualities relevant to drainage, infiltration and erosion potential.** Refer to the soil descriptions for the relevant Biozone listed in Chapter I. In general, Bernalillo County soils are deficient in organic matter and tend to be alkaline (moderately high pH). West Mesa Biozone soils are predominantly sandy, whereas the soils in the Rio Grande Valley Biozone have high clay content. Soils in the East Mesa, Foothills and Mountains and East Mountains are gravelly with some loam and silt. Soil maps for some areas can be downloaded from the National Resource Conservation Service website at http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm. Soil testing can also help to assess the type and health of the soil. Soil test kits are available at County Cooperative Extension Offices and at most garden centers. A good soil assessment is necessary for determining whether amendments are needed. At a minimum, most tests include analysis of soil pH (percent hydrogen ion; an indicator of soil acid-base level), the amount of organic matter, the soil's drainage potential and amounts of basic nutrients present such as nitrogen (N), phosphorous (P) and potassium (K). Once basic information about the soil is known, decisions about how to prepare the soil for planting can be made. Choosing native or adapted plants that prefer the existing soils and local climate can eliminate the need for amending the soil and generally achieves a higher level of water-efficiency. Soil amendments can be added if required based on results of soil testing to address deficiencies or issues such as compacted soils. For example, organic matter such as composts, peat, and manure, incorporated into the soil, can loosen compacted soil, lower the pH, and provide food for beneficial soil microorganisms. Products that increase the water-holding capacity of soil include super-absorbents, which are commonly polymers of various origins, mineral-based products like Zeolite, or organic by-products from manufacturing such as coir. For additional information on amendments see the "Soil and Soil Amendments" sections in this document.

4. **Develop a conceptual site design.** The conceptual plan should utilize data gathered during the site analysis phase to take advantage of site resources and conditions in determining the layout of areas for various site uses. In addition to basic site design of public and private areas and circulation flows, functions to consider include water conservation, stormwater management and water harvesting and climate moderation. Decisions should also be guided by the amount of water and maintenance required for each function.

5. **Include Water-Harvesting Features.** Capturing rainwater that falls on the property and storing or diverting it to planted areas is another way to increase water efficiency and can save thousands of gallons of potable water a year. Site design should strive to achieve zero stormwater or irrigation runoff from the property. Information on a wide range of water-harvesting options is provided in the "Water-Conserving Landscape Devices and Best Management Practices" section of this chapter.

6. **Use the Concept of Hydrozoning.** The landscape should be designed based on hydrozones, which group together plants with similar water requirements. This approach facilitates both efficient irrigation design and plant health. Each hydrozone contains plants that share similar water needs such as High, Moderate, Low and Very Low. Typically three hydrozones are used. Plants with the highest water use or greatest density are placed closest to the building(s) in areas that are highly visible and most heavily used by occupants or visitors to the site. These higher-water-use areas or "oasis" zones require supplemental irrigation and may include turf grass. Shady areas and places where water tends to collect can also be appropriate for higher-water-use plantings.

   Farther away from building,s or in areas of lower human use, the landscape can be less dense and incorporate plants with intermediate to low water requirements. The water needs of this "transition" zone will therefore be lower than that of the "oasis" zone.

   The outermost zone at the site periphery is generally the lowest water use or "arid" zone and has a still lower density of plantings, often composed exclusively of drought-tolerant or native plant material in a more naturalistic planting scheme. Larger lots may have multiple zones, while smaller lots can have smaller or fewer zones. (See Figure 47 and Figure 48).

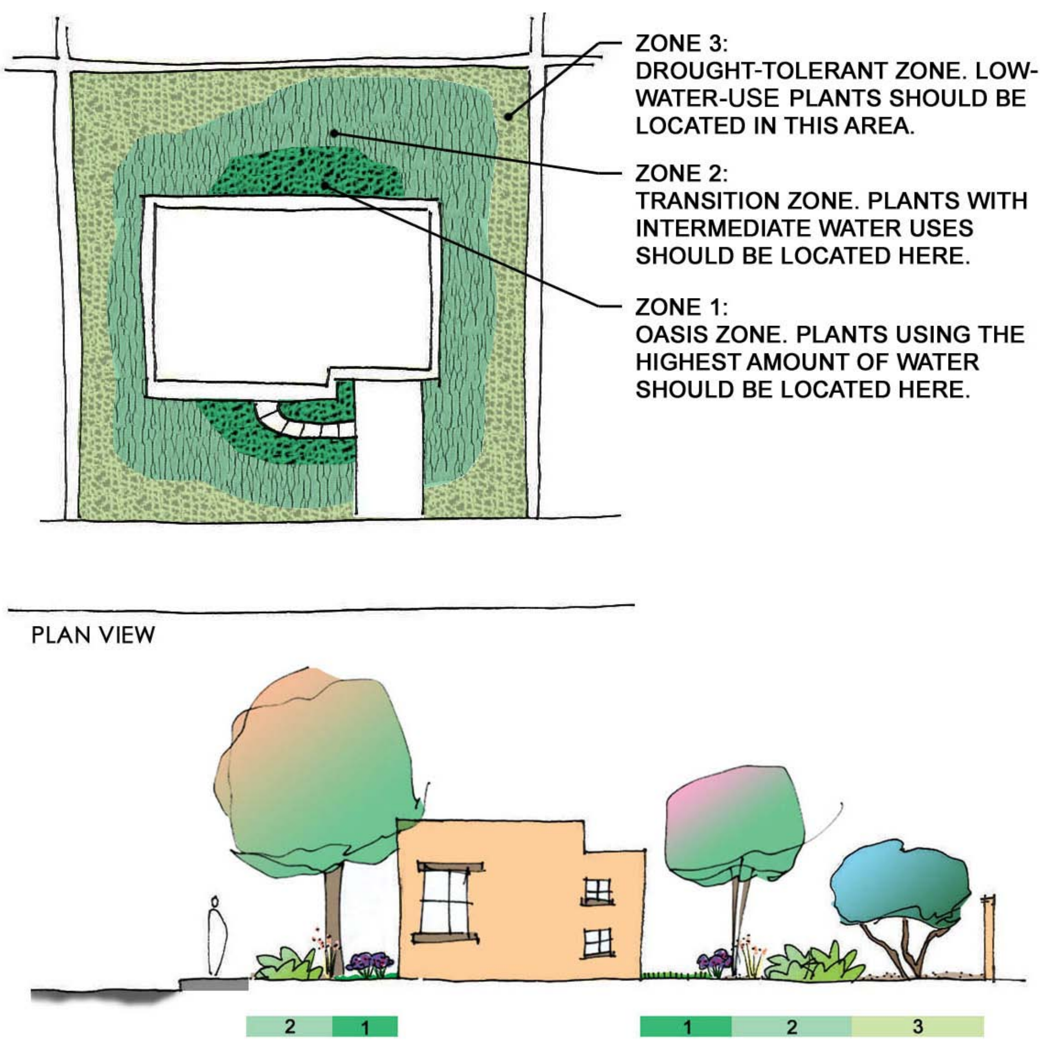


Figure 47. Hydrozones for Large Lot Landscape

In addition to hydrozoning there are three foundation concepts for water conservation that should be incorporated into the site plan and landscape design. These concepts are explored in detail in the "Key Concepts of Water-Conserving Landscape Design" on page 102.

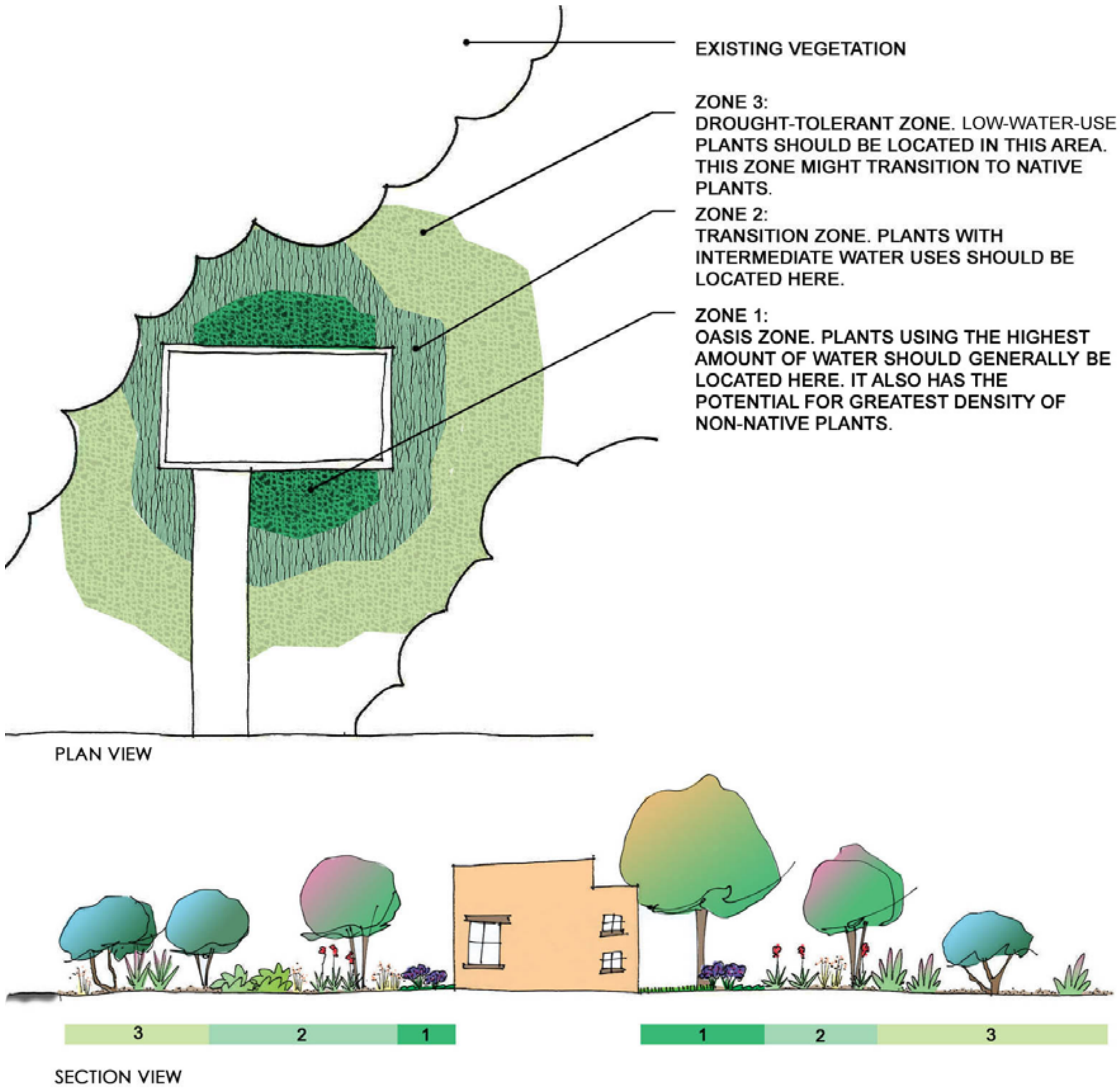


Figure 48. Hydrozone for Small Lot Landscape

7. **Select Plants.** Things to consider when selecting plants include function, water, sun and shade requirements, as well as frost tolerance, maintenance needs, pollen potential, and aesthetic considerations. Selecting and placing plants where they will thrive requires understanding both the average climatic conditions of the area and the microclimates created by particular features. Climate and microclimate conditions to consider include length and direction of sun exposure, reflected heat, wind exposure and frost. Native plants are generally the most water-efficient. They generally do not require fertilizers or soil amendments as they are adapted to local soils and climatic conditions. Non-native drought-tolerant or low-water-use plants can also be excellent options.

   The planting plan should be based on mature plant sizes to avoid issues such as violating clear sight lines at traffic entry and exit locations and the need for excessive pruning to address overcrowding or blocked views. Plant placement can also mitigate extremes of heat, cold and wind, helping to lower utility costs. For more information see "Thermal Effects of Landscape" later in this chapter.

The Albuquerque Bernalillo County Water Utility Authority (ABCWUA) has developed an extensive plant list that provides information on a wide range of plants, including their water requirements, mature size, light needs, pollen potential and landscape use. Copies of the plant list are available at local libraries, nurseries, home garden centers, and community centers as well as through the ABCWUA.

High-water-use lawns are a traditional landscape mainstay. As awareness of water supply and other environmental issues increases, however, acceptance of more water-conserving alternatives is also rising. Traditional high-water-use turf can consume as much as 20 to 31 gallons of water per square foot annually, and requires frequent maintenance such as mowing and fertilization. A range of low-water-use, low-maintenance turf grasses and ground covers are now available and present excellent alternative design options.

Lastly, install the plants themselves with water conservation in mind. Generally speaking plants, whether trees, shrubs, or ground covers should be installed at an elevation lower than the ambient land around them or with basins. This is done to ensure that irrigation that is applied to the plant will remain where it is needed at the plants roots. As the plant grows the basin will need to be graded to maintain its water holding capacity and potentially widened to accommodate the plants growing root system. In "Appendix K. Plant and Turf Grass Installation Details" we have included a range of diagrams showing how plants should be installed in Bernalillo County and the desert southwest for a reference.

Turfgrasses too should be planned for water conservation. They should be installed a low points on the site if possible to capture water from landscapes and drainage at higher elevations. Turfgrass areas should not be bermed for water conservation. Also, planting grasses on slopes should be avoided. When installing turfgrasses the finished grade should always about 1" lower than adjacent surfaces such as sidewalks, drivepads, mulches and other surfaces to allow for drainage. See "Appendix K. Plant and Turf Grass Installation Details" for details on installation.

8. **Design an Efficient Irrigation Plan.** An efficient irrigation system is critical for water-conserving landscapes. An irrigation system based on hydrozones can significantly reduce landscape water use by providing irrigation system zones that match hydrozone plant group water requirements and allowing the groups to be watered separately. In order to achieve maximum water efficiency, it is necessary to use the appropriate type of irrigation for each hydrozone, such as drip irrigation for lower-water-use plant groups and bubblers for trees. The irrigation system should be designed to apply water efficiently, have the flexibility to change with plant needs, be easily operated by the owner or maintenance crew, and be properly installed. For more information regarding water-conserving irrigation systems and strategies refer to the "Water-Conserving Irrigation" on page 154.

9. **Use Mulches.** Mulches minimize evaporation of soil moisture by covering and cooling the soil. They also reduce weed growth and help to prevent soil erosion. Mulches are classified as organic or inorganic. Typical organic mulches are bark, wood chips, straw, leaves, hulls, compost, peat moss, pine needles, and grass clippings. These materials improve soil texture and fertility as they decompose. Organic mulches tend to float and may not be the best choice for water-harvesting areas. Inorganic mulches include crushed rock, stones, gravels, glass, and synthetic materials and generally deplete more slowly than organic mulches. Cobble, larger gravels and decorative rock help stabilize swales, spillways and berms, reducing erosion and evaporation. Mulching with either type increases infiltration by slowing water movement and absorption. It also slows evaporation of infiltrated moisture by covering and cooling the soil. Mulch should not be placed directly against trunks of shrubs and trees as it can cause rot or fungi. Both organic and inorganic mulches should be periodically replaced as they break down and deplete over time. Do not use black plastic or other impermeable coverings under mulches. Impermeable coverings prevent water and air from circulating into the soil and trap condensation, creating ideal conditions for mold, cockroaches and other pests. If an underlay is desired, use landscape or filter fabric under mulch; this allows water and air to infiltrate while initially preventing weed growth. For additional information on mulch types and application see "Mulches" in the "Water-Conserving Landscape Devices And Best Management Practices" section of this chapter.

10. **Plan for and Practice Proper Maintenance.** Determine the level of maintenance that will be supported, as this will influence site landscape design choices. The amount of maintenance required will depend upon plant selection, mulch type and features such as water-harvesting devices included in the landscape. Newly installed landscapes will generally have a higher number of weeds during the first three years due to soil disturbance. Mulching will help to control weed germination levels; removing weeds prior to their setting seed will save on maintenance time in the following growing season. Preventative maintenance is a good investment as it saves time and money over the long run. A well-designed and constructed xeric landscape generally requires only minimal upkeep that includes regular inspection of irrigation and water-harvesting devices, litter clean-up, weed elimination, and timely pruning and mowing.

C. Key Concepts of Water-Conserving Landscape Design

The basic concepts for designing a water-conserving landscape are:

1. Minimize disturbance to prevent soil erosion and preserve existing site resources.
2. Retain and infiltrate water as close to where it falls as possible.
3. Maximize the amount of permeable surface on the land and make impermeable areas as small as possible.

1. Minimize Disturbance

Limiting disturbance will help to protect and preserve the existing site resources, which can make a significant contribution to achieving a sustainable and water-efficient site. Disturbance minimization should be included as an objective in all phases of a development project, from planning and design through construction and occupancy.

Surveying is one of the earliest activities associated with site development that has potential to disturb and damage site soils and vegetation. If the survey method being used requires clear line-of-sight care should be taken to note expectations that vegetation and other features be left intact, and that they be worked around if necessary. Newer survey technologies based on GPS (Global Positioning Systems) or three-dimensional laser imaging can avoid line-of-sight issues altogether.

Determining site layout is the next step in the planning and design process, and the considerations outlined below should be incorporated into the decision making process.

The overarching objective is to maximize water conservation through the design. Several key strategies support this objective. In addition to minimizing disturbance, capturing and infiltrating precipitation as close to where it falls as possible and retaining existing natural drainage patterns are basic principles of water-conserving site design layout. If the site has seen prior development and the natural drainage pattern has been altered, consider how to balance those changes with restoring or emulating the pre-development pattern.

Think about the underlying soils and geology as you map how water will move through the site (the conveyance system) and where it will collect and soak in. Different types of soils and sub-soils have varied capacities for infiltration and can help your system to function more efficiently. Soils with poor infiltration capacity can also be amended, and a wide range of sub-surface measures can be used to increase detention and infiltration rates.

Minimizing Disturbance during Construction - Best Management Practices for Construction Site Runoff Control and Water Conservation

A comprehensive approach to addressing and minimizing construction site runoff should include the following areas (adapted from Brown and Caraco, 1997):

a. Minimize Clearing and Grading

Limit clearing and grading to the minimum area required for the build-out. Take all possible measures to avoid clearing or grading highly erodible soils, steep slopes, stream buffers, wetlands, springs or stormwater infiltration areas. The site limits of disturbance should be mapped and clearly delineated with flags, fencing, etc. Construction personnel should be made aware of expectations regarding the limits of disturbance.

b. Protect Waterways

Clearing and grading activities near waterways should be kept to a minimum, Silt fencing and/or earthen dikes should be installed to prevent deposition of sediment from the construction area into the waterway.

c. Limit Soil Exposure Through Phased Construction

Divide construction into phases and limit grading activities to the phase currently under construction in order to decrease the time that soil is exposed. This helps to decrease the potential for erosion. Subsequent construction phases should begin only when the last phase is near completion and exposed soil has been stabilized. Construction scheduling should include installation of erosion and sediment control measures prior to construction start, and should state time limits for soil stabilization after grading per phase.

d. Immediately Stabilize Exposed Soils
Soils exposed during construction should be stabilized as quickly as possible, and within no more than two weeks of being exposed. If permanent stabilization measures cannot be put in place within the two-week window, temporary erosion control measures should be used to protect the soil. Following are temporary control measures.

- Seeding is appropriate for areas where vegetative cover is the most effective and practical soil stabilization technique. It can also be used on rough-graded areas that will not be regraded for at least one year or one growing season. Seeding plans should include a detailed seed list, as well as seeding application requirements such as timing, mulching, and irrigation in order to achieve good germination rates and successful vegetation establishment.
- Soil roughening is a temporary stabilization technique that involves tilling, tracking or scarifying. It can be used to address areas of disturbance when revegetation efforts are limited due to seasonal planting requirements. Roughening can be done either after final grading, or for temporary stabilization of areas that will be inactive for a short time during the construction period. The depressions created by roughening should be between 2 inches and 6 inches deep and spaced approximately 6 inches apart. Roughening should follow the contours of the sloping areas. If construction equipment is used to perform the tracking, care must be taken to avoid over-compaction of disturbed soils. Roughening is not effective for sandy or extremely rocky soil types.
- Geotextiles or pervious filter fabrics can be used for matting to stabilize flow channels or swales and to protect seedlings on slopes until established. They are also useful for temporary protection of exposed soils, such as temporary soil piles left overnight during construction. They can also be used to separate and enhance the effectiveness of erosion control measures like rip-rap by preventing soils from eroding underneath. For all applications, the geotextile must be properly anchored to achieve continuous contact with the soil surface to avoid potential erosion underneath it.
- Gradient terraces or stepped slopes prevent or reduce erosion damage by collecting, slowing and redistributing runoff flows while increasing the amount of overland flow. They are suitable for use on sloping areas lacking existing vegetation but require stable runoff outlets to direct exiting runoff to appropriate receiving areas. They are not suitable for slopes composed of shallow, sandy or rocky soils.

e. Protect Steep Slopes and Cuts
Avoid cutting and grading steep slopes (slopes in excess of 15 percent). For these sites, diversions or a temporary slope drain should redirect all water that flows onto the slope. Silt fence should be installed at the top and toe of the slopes during the construction period and left in place until revegetation efforts have succeeded. To facilitate revegetation on steep slopes, techniques such as straw or compost wattles, and/or geotextile erosion control blankets should be used along with seeding or mulching.

f. Install Perimeter Controls to Filter Sediments
The entire perimeter of the construction site should have properly installed silt fencing. The addition of a fiber roll or wattle applied on the site-facing or internal side of the silt fence will provide additional sediment filtration capacity. For areas that experience heavy runoff flows, a properly sized earthen dike with a stabilized outlet should be created. Adequately-sized inlet controls also should be included at catch basin inlets that receive stormwater flows from the construction site.

g. Use Sediment Settling Controls
Temporary sediment basins should be created where space is available to detain runoff and allow sediment to settle out. It is important to ensure that discharge from basins is non-turbid. Using multi-cell basin design and skimmers will increase sediment drop-out rates.

h. Train Contractors on Stormwater Site Plan Implementation
Contractors and construction staff should be trained on the installation and use of required erosion and sediment control measures and processes.

i. Control Waste at the Construction Site

Plan for, document and educate construction personnel about site construction waste disposal (including discarded building materials, concrete truck washout, chemicals, litter, and sanitary waste) and how waste materials will be dealt with to minimize adverse impacts to water quality. Plans should designate waste material storage areas and ensure they are located away from catch basin inlets and waterways.

j. Inspect and Maintain Best Management Practices (BMP)

The site stormwater plan should address site construction runoff and erosion control as well as BMP inspection procedures and frequencies. Inspections should occur at a regular intervals and immediately before and after precipitation events. The plan should also describe how BMPs will be maintained.

k. Site Layout

Designing the site to take advantage of, and conform to, existing drainage patterns and topography minimizes disturbance and uses site features and resources to achieve environmental efficiency and conserve water. The placement of buildings and other built elements on the site should be based on data gathered during site analysis and take into consideration:

- Minimizing disturbance to natural water flow pattern on the site as noted above. On-site observation of flows following a storm event can be helpful in interpreting site analysis data. Erosion patterns are also a useful clue to actual stormwater performance.
    - Existing arroyos or drainage swales are important elements of the sites stormwater conveyance network and can be used as naturalistic landscape areas.
- Grade changes that can direct water away from structures and toward useful purposes such as landscaping.
- Whether any runoff flows onto the site from adjacent properties, or whether flows from the site currently run onto other properties.
- Existing water collection points that may be useful as post-development infiltration areas.
- Required setbacks based on zoning type.

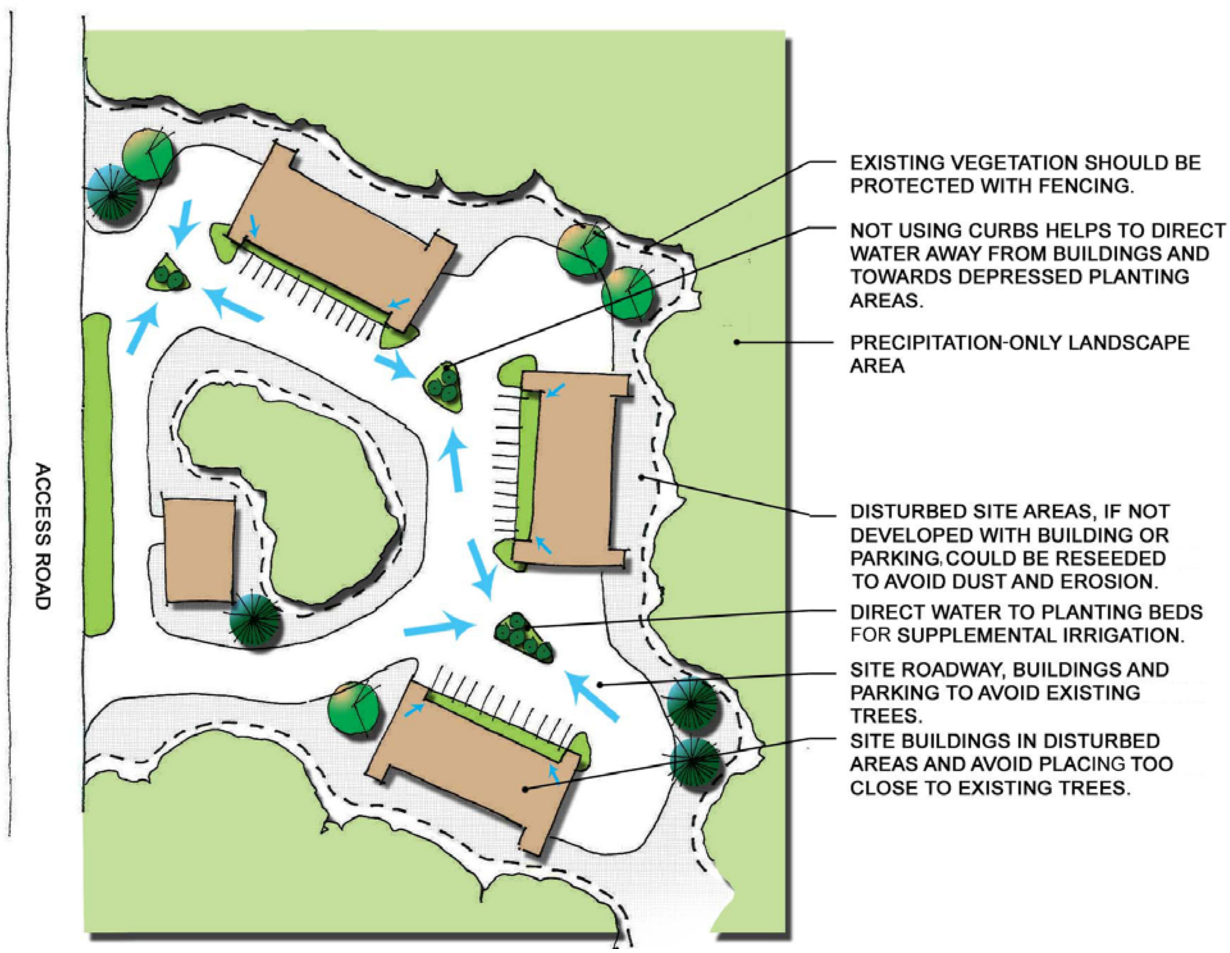


Figure 49. Site Layout for Water Efficiency

The site development footprint should be minimized to the extent possible, allowing increased permeable surface and retention of existing drainage networks, soils and vegetation. Using previously disturbed areas for the building can avoid additional site disturbance.

Significant existing resources may warrant preservation. Assess the resources for their value in preserving the existing site drainage pattern and providing benefits such as water collection points or shade, and determine if they can be retained. For example, existing trees can break the prevailing wind, block unpleasant views or moderate heat around buildings or outdoor areas. The water and soil conservation benefits provided by existing mature plantings are significant and already available, so consider saving existing mature trees and other vegetation and natural features that contribute to water conservation. If you do plan to incorporate existing vegetation in the new development design, be sure to provide appropriate protection during construction. Supplementing existing native vegetation with additional plantings or seeding can also help to increase water conservation and prevent erosion.

Analyze how traffic will flow onto and within the site. Options for access to the site are often limited by regulations, but minimizing the lengths and widths of roads and access drives as well as pedestrian walkways can have a large impact on water flow patterns and should be considered. The location of driveways, roads and walkways should strive to minimize disturbance to vegetation and soils and to hold water on the site or convey it into harvesting and infiltration areas.

Vegetation, particularly trees and large shrubs, should be protected from disturbance by planning for buildings, paved areas and utilities to be located away from them if possible. Once the site and building location have been explored from a water-conserving perspective, designing the functional elements can begin.

2. Retain and Infiltrate Water as Close to Where it Falls as Possible

The topography of a site influences the way water moves across the land. Water-conserving landscape design takes advantage of and builds on existing and new site features to create opportunities for water to infiltrate wherever possible. This can be done by using or enhancing existing features such as depressions, or by creating new features through land forming or grading.

Below are a few of the basic site-related features and techniques used for watershed management and drainage based on the underlying principle of capturing precipitation and letting it infiltrate as close as possible to where it falls.

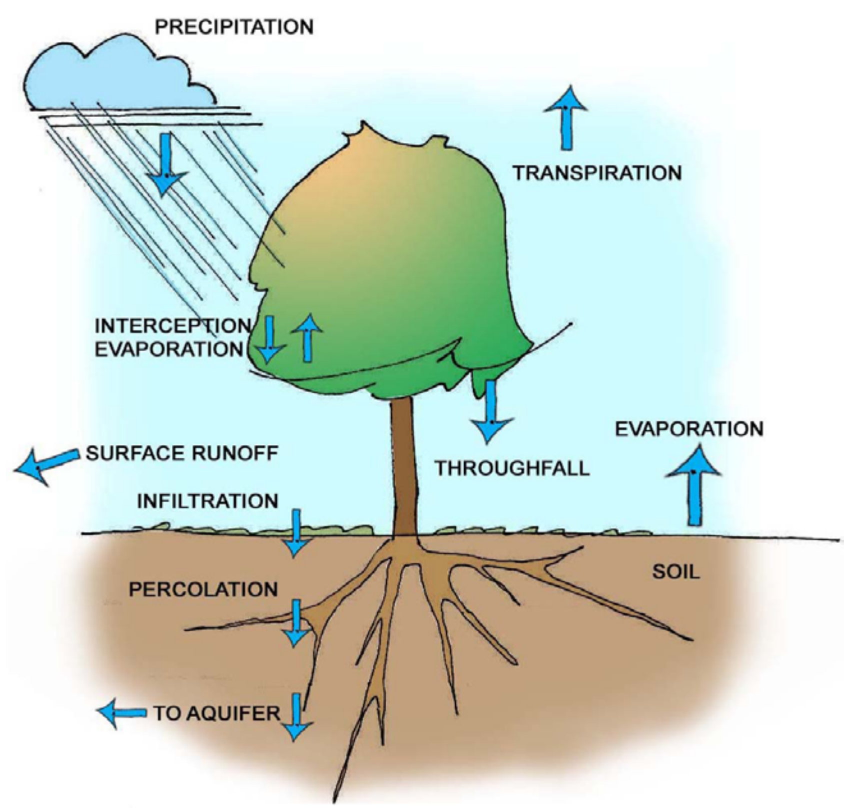
Slope

The slope, or the degree to which land rises or falls, influences how fast water travels over the soil surface and the rate at which it infiltrates the soil. Slope also indicates which direction water will travel once it hits the ground. In addition to assessing slopes on the site being developed, parcels adjacent to the site should be analyzed for potential stormwater flows entering or exiting the site.

Grading and Drainage

Conventional site design strives to direct stormwater off the site and into the storm drain system as quickly as possible. Water-conserving site design tries to imitate or replicate the predevelopment flow patterns, allowing rainwater to collect and infiltrate as close as possible to where it falls. The diagram in Figure 50 illustrates the water cycle. Understanding this cycle and putting this knowledge to work in the landscape can help to maximize water conservation. Allowing rainwater to infiltrate the soil as close as possible to where it falls is the most efficient water conservation method of all. Retaining and infiltrating stormwater on-site provides excellent quality water to vegetation at no cost. At the same time, it minimizes runoff, which helps to reduce the amount of infrastructure required to avoid flooding and erosion. In addition, allowing infiltration of rainwater can recharge groundwater and, in some instances, the aquifer. The "Water-Conserving Landscape Devices And Best Management Practices" section in this chapter contains information on a variety of ways to capture and infiltrate water on your site. Be sure to check with your governing agency to see if there is an existing Grading & Drainage Plan that might restrict what you can do on your property or if your plans require the submittal of a Grading & Drainage Plan.

An integrated site design includes ways to capture and direct runoff to where it can be used to supplement landscape irrigation, improve water quality and recharge groundwater supplies. Where possible, natural arroyos and drainageways should be retained and integrated into the site design. If that isn't possible, the site should be graded to direct stormwater to swales or ponding areas to prevent it from flowing onto adjacent lots. Keeping stormwater on-site provides free water for landscaping and reduces the amount of stormwater flowing into the storm sewer system.



THE RAIN INFILTRATION CYCLE SHOWS RAINFALL STARTING WITH PRECIPITATION FROM STORM EVENTS. WATER THEN EITHER EVAPORATES BACK INTO THE AIR OR INFILTRATES INTO THE SOIL. AFTER THE WATER INFILTRATES THE FIRST LAYER OF SOIL, IT THEN PERCOLATES INTO NEARBY PLANT ROOTS AND EVENTUALLY INTO THE AQUIFER.

Figure 50. The Hydrologic Cycle

The term watershed is used to describe an area within which all the stormwater drains to common collection points. Several smaller watersheds may be identified within a larger watershed, as illustrated in Figure 51. Water does not respect property boundaries, so it is necessary to anticipate flows from upstream in the watershed as well as those from within the site that is to be developed. Ideally, watershed management begins at the top of the watershed. The goal is to keep the volumes released close to historical or pre-development amounts. Capturing and using stormwater within the site is a more efficient method of management and reduces the potential for erosion problems. Drainage features for larger sites include collection points such as buildings, parking lots and plazas; conveyances and drainageways such as swales, conduit and pipes; in-line basins, retention and detention ponds; and outlets.

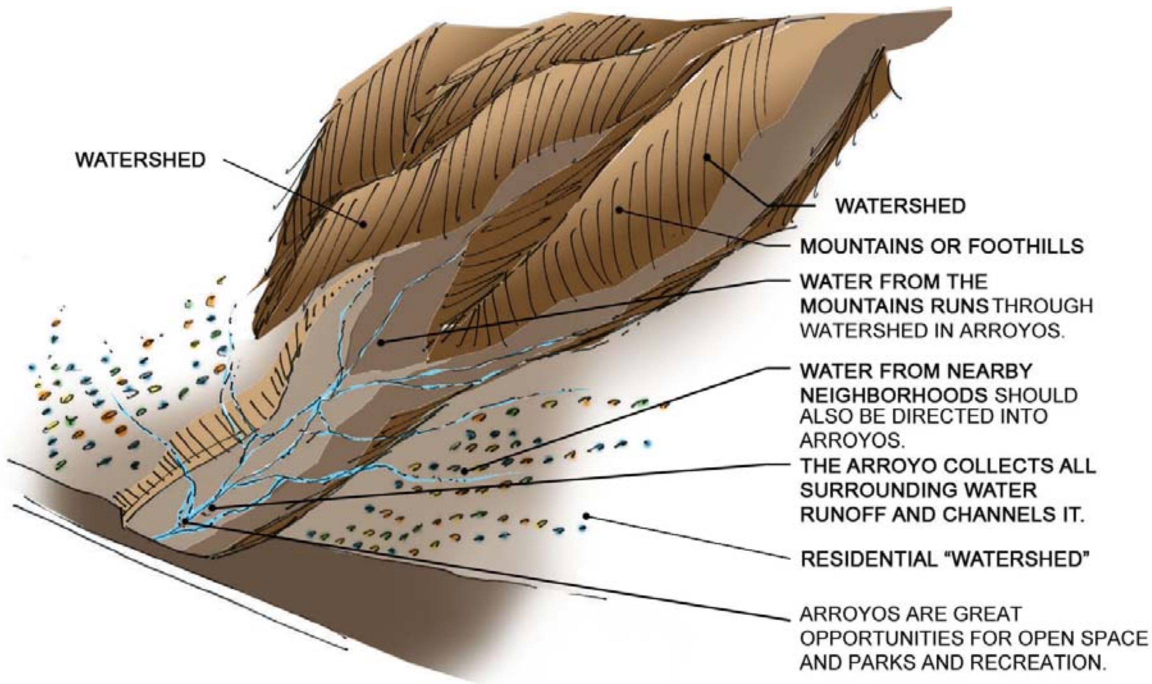


Figure 51. Interconnected Watersheds

It is not always possible to maintain historic flows when developing a site, because when large areas of land are converted to impervious surfaces, the volume of stormwater increases (as illustrated in Figure 52). This increased stormwater volume requires increasing the capacity of drainage facilities. Any changes in the topography of the site will affect the movement and infiltration of water. Thoughtful grading can integrate attractive and functional on-site water-harvesting systems with areas for buildings and attendant structures. As every site is unique, the appropriate location and size of any water-harvesting technique must be based upon the conditions of that site. Grading should direct water away from structures and toward landscaped areas or drainage features that empty into landscape features whenever practical. In addition, paved surfaces such as sidewalks, plazas, and parking areas should be sloped to direct water to drainage ways or landscaped areas as much as possible.

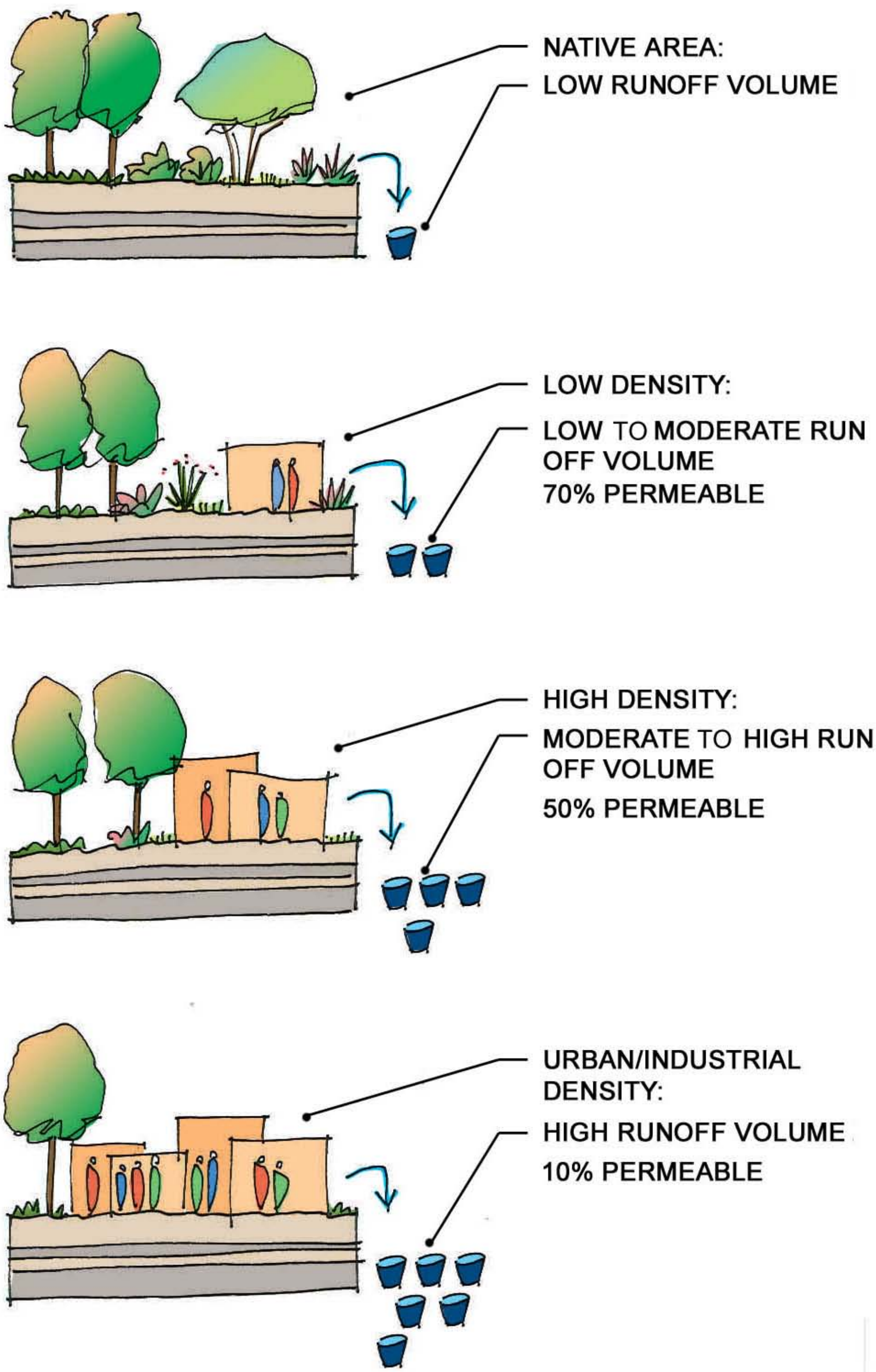


Figure 52. Relationship of Development Density to Permeability and Runoff

The illustrations in Figure 53 and Figure 54 show how stormwater can be used on site by directing it to such features as swales, parking islands, buffers and other like features.

Figure 53. Parking Island Water Harvesting Microbasin

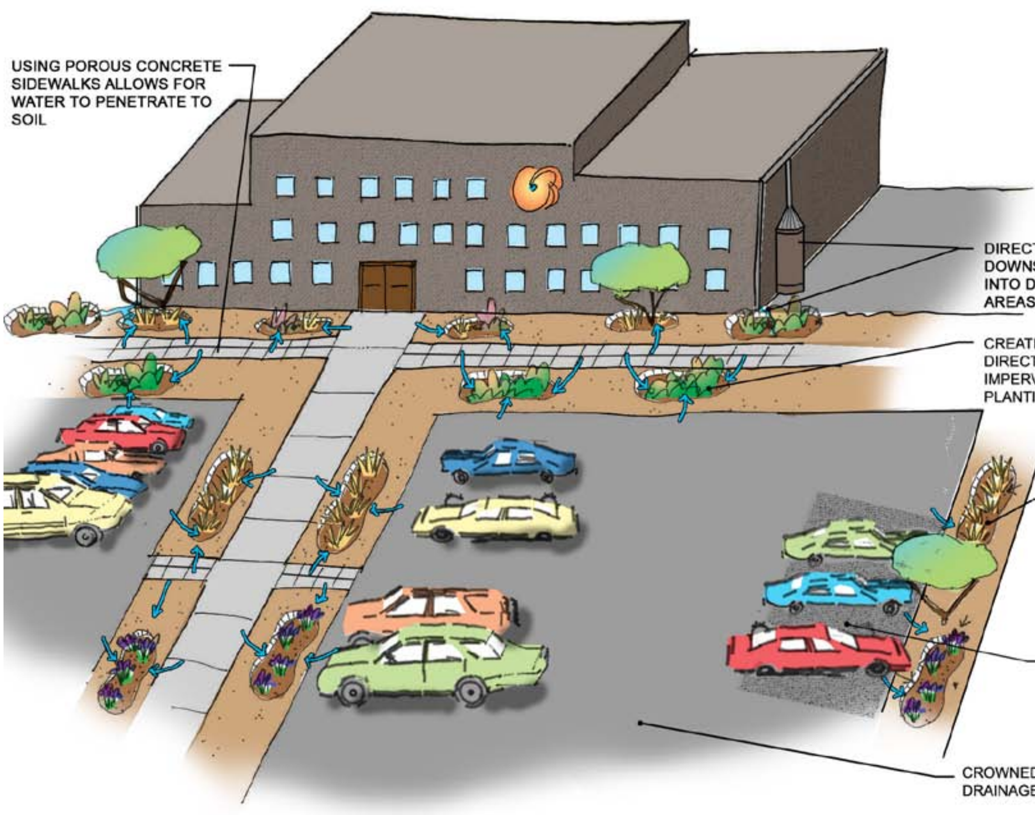


Figure 54. Site Water Harvesting

Graded depressions in the landscape create opportunities for water to collect and infiltrate. They are very beneficial when used for planting areas. Shallow depressions or basins can be sufficient; the larger the area they encompass, the more water they will retain. As one inch of water can penetrate the soil to a depth of about one foot, a very shallow 1-inch depression would permit a 1-inch rainfall to permeate the entire root zone of a groundcover. This would be proportionate for larger plants, such as shrubs, whose root zones are about 2 feet deep, and trees, whose root zones about 3 feet deep. Depressions of at least 2 inches deep (for shrubs) and 3 inches deep (for trees) would suffice for complete penetration if the basin were full. Increasing the depth of depressions will allow rain from larger precipitation events to pool and infiltrate; helping to decrease the amount of runoff that may contribute to erosion on the site. The depressions also assist irrigation efficiency by retaining irrigation water where it is needed for the plants until it infiltrates.

Areas with poor drainage, such as those with clay or caliche lenses, can benefit from the creation of drainage chimneys. A drainage chimney is simply a deep hole that either pierces the hard soil layer or provides a place for subsurface water to drain. Fill the hole with gravel and mulch the top at a level consistent with the rest of the landscape area. Plants placed around the edge of chimney can use the water held there.

Dry washes—shallow, winding swales lined with irregularly-sized stones—can help to slow and direct runoff to desired locations in the landscape.

3. Maximize Permeability

Reduce Impervious Surface

It has been said that we are "paving our way to drought." This statement points to two results of covering the earth with impervious surfacing. First, when impermeable surfaces prevent stormwater from infiltrating the ground, the opportunity to recharge groundwater or the aquifer is lost. Second, impermeable surfaces increase the absorption of heat from the sun and reflect it to surrounding vegetation and the atmosphere, creating demand for more water for plant growth and to cool structures and people. Water-conserving site design strives to minimize the amount of impermeable paved surface area. It does this through efficient design and layout of all site elements requiring paved or hardened surface area, including those that deal with circulation and vehicle access. Techniques that can reduce total impervious surface on site include designing those areas to the smallest footprint required for their function, using alternative permeable paving materials, and breaking up the total area using pavers, brick, flagstone or other paving materials that allow water to infiltrate between the individual pieces.

Impermeable Paving

Other than rooftops, the majority of non-porous surfaces on a commercial lot are paved parking lots, access roadways and pedestrian walkways, typically built of concrete or asphalt. As noted previously, many outdoor surfaces do not necessarily have to be completely waterproof and those that are can be crowned or sloped to shed runoff into landscape and water-harvesting areas as shown in Figure 55 . The best way to accomplish this is during initial grading and construction. Paved surfaces should be oriented so that they slope away from structures. In addition, low points should be located where runoff can be intercepted and retained, allowing the water to be utilized by landscaping.

Breaking up large areas of paving to provide areas for runoff to collect and infiltrate can mitigate the impact of large areas of impermeable pavement. Parking lot islands provide an excellent location for landscaped microbasins. Curb cuts allow stormwater to drain into planting beds. For more information, see the "Water-Conserving Landscape Devices And Best Management Practices" section. The planting beds should have a lower finished grade than the contributing surface with at least three inches of gravel mulch to prevent erosion of basin soils and reduce evaporation loss. Plant materials should be tolerant of both drought and periodic inundation, and not be adversely affected by contaminants such as oils and other hydrocarbons from cars. Native grasses have been shown to meet these criteria.

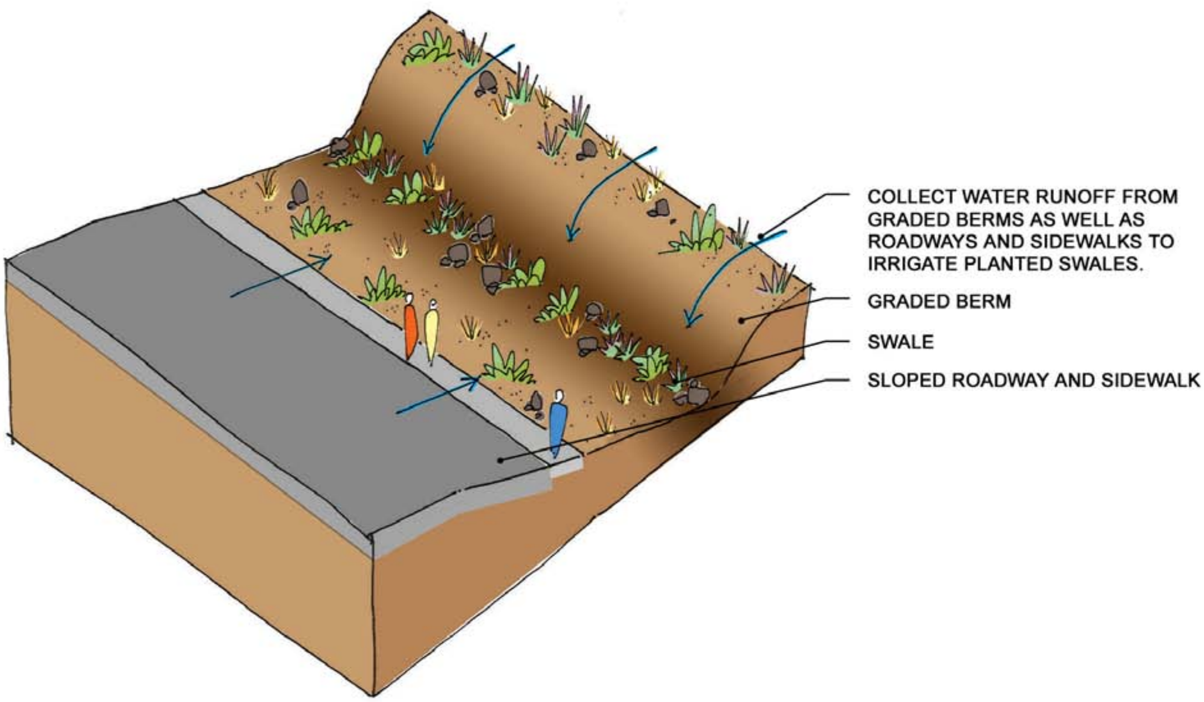


Figure 55. Water Harvesting from Sidewalk

Permeable Paving

Various types of porous paving products are currently available. Turf blocks, grasspave, and pervious concrete provide the stability of traditional paving with the advantage of allowing stormwater to permeate the surface. These surfaces are ideal for parking lots. Crusher fines, when stabilized, are ideal for walkways and outdoor break room/recreation areas.

Pervious concrete, also known as "no-fines" concrete, has a built-in void structure of 15% to 25%, which allows water to pass through. Many pervious paving surfaces have the added benefit of lowering heat island effects by as much as 12 degrees Fahrenheit when compared with standard dark pavement. The use of pervious paving saves money in two ways: 1) Reducing stormwater impact fees and 2) Increasing the amount of usable land that otherwise would have been dedicated to stormwater retention ponds.

There are also various types of pavers that create openings between the pavers that allow water to pass through. These spaces and can be filled with either gravel, grass or groundcovers (see Figure 56). For additional information see the "Water-Conserving Landscape Devices And Best Management Practices" section of this chapter.

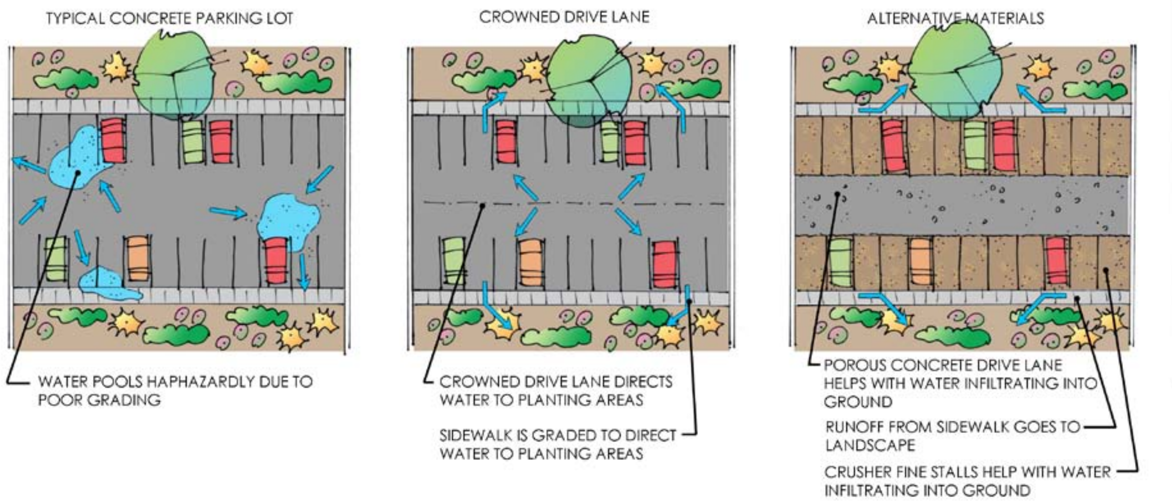


Figure 56. Alternative Paving and Grading Approaches for Water Harvesting

Prevent Erosion

Erosion is evidence that water is moving too fast to infiltrate. Areas showing evidence of erosion need to be considered when designing the layout of the development in order to mitigate and avoid worsening the situation. A properly graded site spreads and slows stormwater runoff by lengthening and reducing slopes, directing the runoff to areas designated for capture and infiltration. Preventing water erosion helps to protect soils and vegetation, which are key contributors to the site's water efficiency level.

A thoughtful approach to site grading can head off erosion issues by assessing the potential impact of grading on water movement through the site. A general rule of thumb is to avoid creating slopes greater than 4:1 as they tend to be highly erosive and difficult to stabilize. Revegetating newly graded steep slopes and cut banks as soon as possible is critical to minimizing erosion. A variety of revegetation plantings can be used, from native grasses to groundcovers and shrubs, all of which can help stabilize and protect the exposed soils. The site grading plan should include provisions for minimizing erosion on newly graded slopes by intercepting all surface runoff and conveying it to stable channels.

Following the site's natural contours will help to preserve natural drainage patterns. Use of devices such as berms and swales can also be used to enhance the natural drainage patterns and prevent erosion. (See the "Water-Conserving Landscape Devices And Best Management Practices" section of this chapter for more information on water conveyance and infiltration devices.)

Additional Landscape Design Considerations

Thermal Effects of Landscaping - Strategically placing trees and other plantings can mitigate extremes of heat, cold and wind, reducing energy costs and water use while providing aesthetic benefits.

- Planting deciduous trees on the south, west and east sides of buildings will provide shade from harsh western sun, cooling them in summer and warming them in the winter. Plantings not only can reduce the use of swamp coolers and air conditioners by more than 30 percent, but also reduce the amount of water consumed by their operation. Irrigation demand can be reduced by grouping trees together so that they shade each other, creating a cooler temperature and higher humidity microclimate.

- Trees planted along north-facing walls can have an insulating effect in winter and summer by adding a layer of living matter between exterior walls and temperature extremes. Evergreen trees and shrubs block wind and also screen unwanted views (Figure 57).
- Shading paved areas reduces heat build-up. The evapotranspiration of "oasis" hydrozone plantings near buildings provides a cooling impact.
- The effects of drying winds can be mitigated by planting rows of tall shrubs or trees.

Chapter I of this document provides information about dominant environmental conditions for each of the Bernalillo County Biozones. This can supplement information gathered during site analysis to determine the optimal placement of plantings for thermal mitigation. Understanding the general climatic conditions that apply to your site is key to applying these concepts. As an example, the prevailing winds at the Albuquerque International Sunport are from the north October through March, the west from April to May, and the east from June through September. In contrast, winds at the Double Eagle Airport on the West Mesa are generally from the north-northwest and west from November through May; and from the south in the summer. Based on this information, a windbreak to block winter winds should be placed on the north side of a building in the East Mesa Biozone but on the north-northwest side of a building in the West Mesa Biozone.

Evolution of the Landscape **-** The various elements of a landscape, including plants, soils and topographic features, are not static and will change over time. This evolution should be considered in landscape planning and design.

Ample space must be given for plants to grow without crowding. Given the smaller initial size of most plants when first placed in the landscape, there is a natural tendency to plant too many plants or to plant them too close together. It is important to allow space for the growth and mature size that plants will ultimately achieve. If plantings are grouped closely together for initial visual impact, thinning to allow appropriate growth should be planned for and performed. The water needs of plants under trees may also change due to decreasing evaporation and establishment as maturing tree canopies expand, requiring irrigation adjustments. The placement of trees should always be based on their mature size so that they are planted far enough away from buildings, structures and utilities to avoid severe pruning or removal.

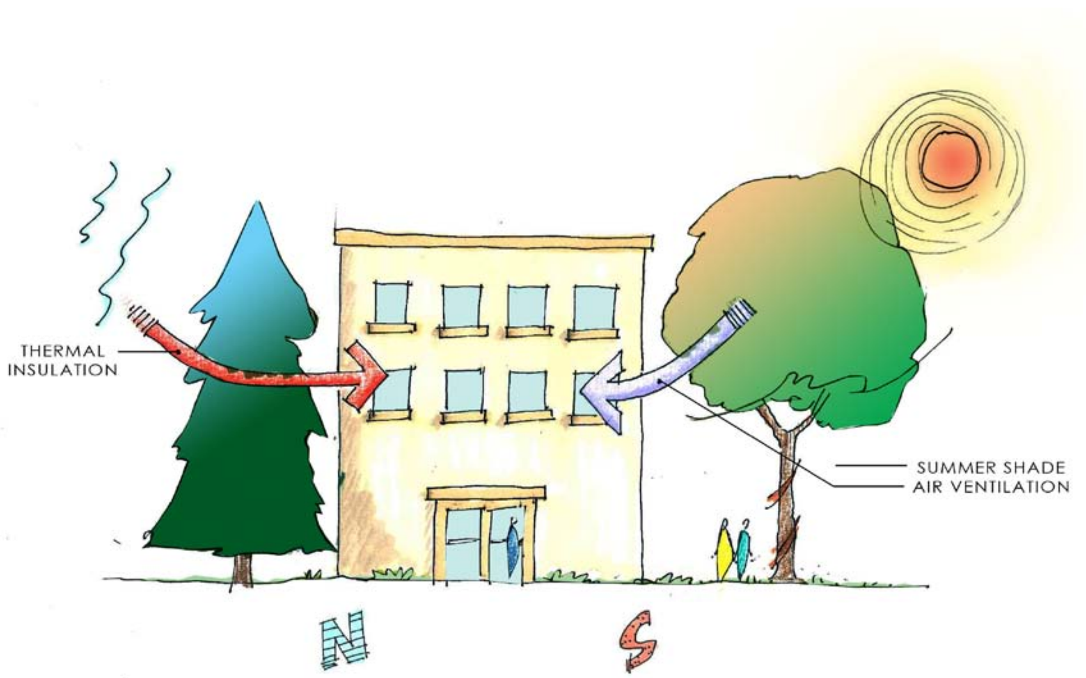


Figure 57. Thermal Mitigation Through Landscape Plantings

Landscape Rehabilitation (retrofits vs. new landscapes) - It is not necessary to completely change an existing high-water-use landscape in order to conserve water. One relatively simple way to improve the landscape's water efficiency is to verify that the irrigation schedule is appropriate to the plant needs and the soil type. Adjustments can be made to the irrigation system or schedule based on the test results (see "Measuring Irrigation Water Applied"). Retrofitting or revamping an existing irrigation system to include newer water-conservation technologies and equipment can also greatly reduce water waste (see the "Water-Conserving Irrigation" section for more information). Increasing the drought-tolerance of plantings by gradually reducing the amount of water currently being used is another option. For example, if plants are being watered every day for 15 minutes, determine whether that amount of irrigation time is soaking the entire root zone depth. If so, the schedule may be reduced to every other day for 30 minutes for several weeks, and then further reduced to every three days and so on until you achieve the watering frequencies recommended in "Appendix I. Recommended Watering Schedules" Remember to monitor the plants for signs of stress and adjust the actual duration and frequency accordingly.

Measuring irrigation water applied

There are two easy ways to measure the amount of water being applied during irrigation

- After the irrigation run is completed, push a shovel into the dirt and then push it back such that you can see how deep the moistened soil goes. Alternately you can use a metal rod as described in the Water-Conserving Irrigation section.
- For measuring sprinkler irrigation place 3-5 straight-sided empty cans at even intervals being sure to place a can near the edge of the area being irrigated. Run the sprinklers for thirty minutes, then measure the depth of water in each of the cans. Add up the depth of water in all of the cans, then divide that total by the number of cans and multiply by 2. The result is inches of water applied per hour.

The first step in rehabilitation and retrofitting is to evaluate the existing landscape:

- How much water does it require for good health? How much water is it getting? How is it delivered?
- Does the landscape serve its function?
- Is there room for improvement (plants past their prime, overgrown their location, causing other problems)?
- Is water running off turf grass that is growing on slopes?

Based on the answers, determine what changes you would like to make (new function, other desired changes) and follow the "Recommended Steps for Water-Conserving Landscape Design" noted above with the addition of these considerations:

- Avoid drastic changes in irrigation to plants that are to remain. If a turf area is going to be changed by replacing it with a low-water-use turf or with other plants, care should be taken to account for any trees or shrubs that may have been benefitting from the turf irrigation. The irrigation system may require adjustment to ensure that these plantings continue to receive sufficient water. It is often unnecessary to replace an entire irrigation system, as kits are available to convert spray irrigation systems to shrub spray or drip systems. Consultation with an irrigation specialist can help to ensure a successful transition to reduced water use.
- Xeriscaping creates a landscape that exists in harmony with the surrounding dry environment, such as replacing turf with colorful, low-water-use plants and mulching with inorganic or organic materials. Replacing turf grass with gravel is not xeriscaping, as it raises reflected heat levels, increasing the water needs of existing plants and use of air conditioning.
- Select the appropriate turf for your biozone and function. For example, Buffalograss thrives in heavy clay soils, but struggles in sandy soils and does not tolerate heavy foot traffic. It is not the best choice for a backyard in the West Mesa Biozone, whereas a fescue blend is better adapted to the soil and use conditions.

Photo 41. Alternatives to Bluegrass Turf

TURF-TYPE TALL FESCUE:

Uses approximately 50% less irrigation than Kentucky Bluegrass. Turf-type Tall Fescue looks like Kentucky Bluegrass but grows in a much wider range of conditions.

TURF-TYPE BUFFALOGRASS:

Uses 75 to 100% less irrigation than Kentucky Bluegrass Turf-type Buffalograss makes a beautiful soft lawn and needs little or no irrigation.

Reclamation and Revegetation - Plant cover should be maximized and existing vegetation retained to the extent possible. Vegetation helps to control erosion by protecting the soil surface from displacement due to the impact of raindrops, and by decreasing the quantity and velocity of overland runoff flows. In addition, plant roots help to keep soil porous and increase its infiltration capacity. Reseeding or revegetating disturbed, degraded or bare areas generally results in a more water-conservative landscape.

The need for reclamation can be reduced or eliminated if care is taken during the construction process. The key steps include:

- Minimizing the area of disturbance by avoiding mass grading and plowing that expose the soil to the sun and wind, increasing evaporation. These practices also destroy existing vegetation that holds the soil and prevents it from being blown or washed away. Restricting construction activity to the minimum possible area limits the total adverse impact to the site.
- Periodic spraying of water or adding commercially available dust control substances over disturbed soil reduces the amount of dust generated. It also helps to maintain a minimal level of soil moisture that improves the germination rate of reclamation seeding. The need for dust control measures can be decreased by keeping the disturbed area to a minimum.
- Revegetating with native grasses and plants helps to protect the soil and reduces water runoff and evaporation. Native dryland seed mixes generally include a combination of warm and cool season grasses. The warm season grasses, such as galleta, sideoats and blue grama, germinate during warmer weather, usually after the summer monsoons. Cool season grasses, such as Indian ricegrass, sprout in early spring. A mix of both types takes advantage of opportunities presented by seasonal precipitation and provides a diverse mix of species. Wildflower seeds can be added to native grass mixes to help bind the soil, add diversity and provide food for insects, birds and other wildlife.
- When seeding with native grasses, sufficient moisture at the right time is critical. Planning for supplemental irrigation if natural precipitation is insufficient will help to improve germination and survival rates.
- Applying crimped straw, or mulching with compost or small-sized aggregate over seeding areas can also help to retain soil moisture and prevent seed and soil from being blown away, increasing successful germination. Mulching also helps to regulate soil temperatures and prevent erosion during the establishment period. Seed germination rates can also be enhanced through soil imprinting, which is described in the "Water-Conserving Landscape Devices and Best Management Practices" section.

Maintenance Practices - Maintenance practices can also be adjusted to conserve water, for example, sweeping sidewalks, patios and driveways instead of washing them off. A hose can deliver five gallons of water per minute, so even five minutes of washing can conserve 50 gallons of water.

D. Water-Conserving Landscape Devices And Best Management Practices

In this section, methods for conserving water in the landscape are described and illustrated. These devices and best management practices can be used to help meet Bernalillo County Water Conservation Ordinance requirements and enable the developer, builder or property owner to conserve water while creating a beautiful and thriving landscape that improves the environment and enhances property value. A complete copy of the Water Conservation Requirements Ordinance (Ch. 30. Art. VII, Sec. 241-256) can be found in Appendix A.

Water Harvesting

The goal of water harvesting for larger scale sites is to direct and reuse stormwater in a beneficial way along its path. Harvesting rainwater means collecting rainwater from impervious surfaces; a building, parking lot, plaza and sidewalks, and capturing it in a tank or directing it away from the point of collection via any of the methods described below. Whether a parcel is large or small and contains a single structure or several, all the water that falls onto the lot can be allowed to infiltrate or be directed to other retention ponds or landscaped areas as much as possible. Figure 49 above shows that there are several methods of directing water to places where it can infiltrate the soil on large sites. Using a combination of techniques maximizes the amount of stormwater that can be harvested and used as opposed to running into the stormwater sewers. Water harvesting methods can be considered as either aboveground or underground.

Water harvesting offers multiple benefits such as reducing the amount of irrigation required, improving water quality, and reducing erosion and the amount of site discharge into the storm sewer system. Water harvesting devices can be used individually or in systems called "treatment trains" to collect and distribute water to the landscape efficiently. The devices can be as simple and small as rain chains and rain barrels, or as large and complex as ponds or constructed wetlands.

Basic Principles for Water Harvesting

- Plan for use of harvested water to support landscape needs.
- Look for water harvesting opportunities throughout the site. Providing opportunities for stormwater to slow and infiltrate as close as possible to where it enters the site or reaches the ground will decrease the need for larger scale interventions downstream.
- Collect, slow and enable stormwater to infiltrate the ground using a variety of water-harvesting devices based on the site conditions and constraints.
- Plan for overflow from all water-harvesting and storage devices used and direct the overflow into the landscape.
- Plan for water quality. Stormwater washes the surfaces it runs over, collecting and conveying pollutants and sediment that have accumulated. The potential amount and type of materials conveyed in first flush runoff should be considered when selecting and designing water-harvesting devices and systems for a site.
- Maintain water-harvesting devices and systems. Plan for and provide appropriate maintenance in order to maximize device and system performance and longevity.
- Make sure that your drainage project does not negatively impact anyone else's property.

Water-Conserving Landscape Device Matrix

The following matrix lists a range of potential water harvesting techniques along with information regarding their use. More detailed information on each technique is available in the text following the matrix.

To use the matrix, locate the desired primary water-conservation function, then follow the rows across to see which devices perform that function. Review the ideal conditions, counter-indications and constraints regarding use and siting for each device to determine whether it is appropriate for your site conditions. If a particular technique is not appropriate for your site, review the other devices listed for the desired function to find other options. A summary of maintenance considerations is also provided to assist in preliminary decision making. After determining which devices are most likely to perform well for your site, review the detailed device descriptions in the section following the matrix to further assist your decision making process.

Device	Primary Water Conservation Function	Additional Functions	Ideal Site Conditions	Counter indications/ Constraints	Configuration / Design Options	Maintenance Considerations / Issues	Detailed Information
Swale	Drainage water conveyance.	Infiltration/ landscape sustainability, flow reduction, flow diversion.	Slopes of 0.5% to 1.5%.	Minimum 0.5 % slope on paved surface, minimum 1.0 % slope on vegetated surface, rip-rap or vegetative armoring may be necessary for high water velocities.	On-contour swales/berms, off contour swales, armored or vegetatively reinforced. Erosion control blankets necessary on slopes of >5:1.	Visual inspection and cleaning after significant rainfall event, landscape maintenance.	page 121
Check Dam	Erosion control along drainageways/ water harvesting.	Decreases water velocity, water quality improvement/ desedimentation, infiltration for landscaping.	Drainage area <10 acres - for every one foot drop in elevation or a minimum of 50- feet separation.	Do not place in live streams (only useful for intermittent drainageways).	Boulder/cobble weirs, wicker weirs, earthen checkdams, concrete.	Visual Inspection for damage, sediment removal, landscape maintenance; drainage should allow slow infiltration but not ponding (to avoid mosquito problems).	page 124
Gabion Structures	Erosion control. Retaining wall.	Decrease water velocity, water quality improvement, infiltration.	Hillsides and drainageways.	Landscaping needs to be carefully chosen, and proper anchorage of base should be designed by engineer to prevent failure of gabion wall.	Terraces, in drainageways.	Visual inspection and cleaning of gabion wire after significant rainfall events.	page 126
Curb Cuts (for Water Harvesting)	Parking lot and street conveyance.	Flow diversion/ water harvesting for parking and streets.	Parking lots and streets adjacent to vegetation and landscaped areas.	Should be installed per the applicable regulating agency standards and methods of construction (Bernalillo County, NMDOT).	Parking medians, streetscape rain gardens.	Because these devices are accepting drainage from streets they need visual inspection and cleaning.	page 127
Rain Chain	Water conveyance for low rooftop flows.	Aesthetics.	Rooftops with canales or gutters.	Large rooftop drainage basins may produce too much water.	Many, constricted only by style.	Sediment cleaning necessary in individual baskets.	page 128
Microbasin	Infiltration devices / water harvesting.	Water quality improvement, small infiltration basins, landscape sustainability.	Parking lots, open landscapes, gentle slopes (slopes less than 5%).	Not suitable for steep slopes, not suitable along swales or major drainageways, may need spillways.	Localized depressions, crescent depressions (for hillsides), parking islands.	Visual inspection and cleaning after significant rainfall event, landscape maintenance, drainage should allow slow infiltration but not ponding (to avoid mosquito problems).	page 129

Device	Primary Water Conservation Function	Additional Functions	Ideal Site Conditions	Counter indications/ Constraints	Configuration / Design Options	Maintenance Considerations / Issues	Detailed Information
Soil Imprinting	Slow infiltration.	Erosion control / water harvesting.	Open land unobstructed with impervious surfaces.	Steep slopes of > than 2%.	Open landscape areas, ideal for reclamation.	During establishment of seed erosion must be abated. After establishment no maintenance should be necessary.	page 131
Waffle (or Grid) Gardens and Terraces	Infiltration, reclamation.	Erosion control, flow reduction.	Steep hillsides (terraces), flat surfaces where cross migration of subsurface water needs abatement.	Extremely sandy or erosive soils.	Terraces and flat surfaces, berms surrounding may need armoring.	Rebuilding may be necessary upon large storm events.	page 131
Permeable Paving	Infiltration from parking and pedestrian areas.	Water quality improvement, groundwater recharge, pollution prevention.	Parking lots and pedestrian areas surrounded by vegetation.	Sand and silt from desert areas can clog openings in pavement.	Asphalt, concrete, or open celled pavers with underlying gravel. Permeable pavement should be sloped a minimum of 0.5% To prevent ponding. If underlying gravel is used as storage area, it must be sized per the design storm.	Periodic flushing, power blowing or vacuuming may be necessary to facilitate drainage, landscape materials should not be stored on surface.	page 131
Bioretention Cell or Basin	Water quality improvement.	Infiltration / aesthetics.	Parking lot (for runoff pollution protection).	Some plants may require irrigation.	Parking lot islands, filter strips on parking lot end points. Design so that a maximum of 6 inches of water is present at design flow to prevent inundation of vegetation.	Landscape maintenance is specialized; irrigation may be necessary, landscape may need replacement periodically to retain functionality.	page 135
Constructed Wetland	Water quality improvement.	Infiltration, water quality improvement.	Sewage treatment, landscape water quality improvement.	Maintain a minimum of 20 feet from any structure. A geotechnical report should be completed to address slope stability of pond embankments. Avoid soils with high infiltration rates (sandy soils). Water inflow should be greater than the site release rate, infiltration rate, and evapotranspiration rate.	Unlined, using soils with high water retention, lined using soils with high infiltration rates.	Routine management of vegetation (replacing dead plants and removal of plant material) and routine removal of sediment. Wetlands should be designed with vehicular access points for proper maintenance.	page 137

Device	Primary Water Conservation Function	Additional Functions	Ideal Site Conditions	Counter indications/ Constraints	Configuration / Design Options	Maintenance Considerations / Issues	Detailed Information
Detention Pond	To detain water in a pond with a stormwater outlet (shorter term storage and infiltration).	Infiltration/landscape sustainability, groundwater storage, water quality improvement.	Large open areas, sandy soils preferred. See configuration column.	Maintain a minimum of 20 feet from any structure. A geotechnical report should be completed to address slope stability of pond embankments.	Size per design storm. Pond should be sized for a minimum 100-yr 24-hr storm and have at least one foot of free board at peak volume. Outlet culvert should be sized to allow the pond to completely drain design volume within 72 hrs. Pond should have a minimum of a 2% bottom slope to allow complete drainage. Pond should be designed with an overflow structure to prevent failure of embankments during extreme storm events.	Visual inspection and cleaning of pond bottom, outfall structure, and overflow structure after significant rainfall events.	page 138
Retention Pond	To retain water in a pond with no outlet (storage and infiltration).	Infiltration/landscape sustainability, groundwater storage, water quality improvement.	Large open areas, sandy soils preferred. See configuration column.	Evapotranspiration calculations must be done to ensure the water in the pond will empty between significant storm events. Mass balace analysis should be done by a licensed engineer. Maintain a minimum of 20 feet from any structure. A geotechnical report should be completed to address slope stability of pond embankments.	Pond should be sized for a minimum 100-yr 24-hr storm and have at least one foot of free board at peak volume. Surface area of pond should be sized to allow for complete evaporation of water volume between significant storm events. Pond should be designed with an overflow structure to prevent failure of embankments during extreme storm events.	Visual inspection and cleaning of pond bottom and outfall structure after significant rainfall events.	page 141
French Drain	Below grade infiltration, flood protection.	Temporary shallow groundwater storage, conveyance, infiltration/landscape sustainability, pollution prevention.	Rooftops with canales, land slopes of 0.5% To 1.5%.	Non-porous / clayey soils (poor drainage), below grade use only, steep slopes. Size according to target flow/velocity (should not drop below 2 ft/s, not greater than 7 ft/s).	Perforated pipe, w/wo gravel bed and filter fabric surrounding, gravel bed with filter fabric (gravel grain size distribution should be such that geomenbrane & perforated pipe do not clog).	Due to below grade installation difficult to clean; if installed with landscape adjacent, difficult to replace/clean.	page 141

Device	Primary Water Conservation Function	Additional Functions	Ideal Site Conditions	Counter indications/ Constraints	Configuration / Design Options	Maintenance Considerations / Issues	Detailed Information
Wicking Systems	Below grade infiltration/ passive irrigation for individual plants.	Minimal drainage protection.	Landscape plantings with minimal irrigation, on-contour swales.	Non-porous/clayey soils (poor drainage).	Must be located near root system of plant.	Due to below grade installation difficult to clean; if installed with landscape adjacent, difficult to replace/clean.	page 145
Mulches (gravel, wood, other)	Reduce evaporation in landscape areas.	Aesthetics.	Landscape areas.	When place adjacent to hard surfaces depth of mulch must be considered.	Matches landscaping.	Most mulches must be periodically replaced, blowing sand and dirt can inundate mulches.	page 146
Rain Barrel	Minor water storage.	Water quality improvement, landscape irrigation.	Rooftops with canales or gutters.	Minimal water storage possible.	Single barrels, multiple barrels installed in series.	Sediment collection or filtering may be necessary, overflow devices necessary.	page 162
Cisterns	Water storage.	Water quality improvement, landscape irrigation.	Availability of non-porous surfaces (i.e, roofs and parking lots).	Cannot collect water from turf grass or graveled surfaces (porous surfaces).	Above and below ground.	Sediment collection or filtering may be necessary, overflow devices necessary.	page 163

Conveyance Devices

These methods are designed to collect, slow, and deliver captured storm runoff to the desired location. They also allow some water to infiltrate into soils as it passes along the conveyance channel.

Swales

Function: A swale is a depressed open channel designed to capture sheet flow runoff and convey it slowly in broad, shallow flow to where it can be stored or used for landscaping. Swales are designed to slow and spread the water to allow pollutants to settle and filter out as the water infiltrates the ground. Swales can be lined with hard materials like rip-rap or cobble, or planted with a range of plant materials to enhance their function. Swales can be built to depths of between one and three feet and with widths of from one to four feet or more, with a roughly equally dimensioned berm on the downslope side. This can be constructed with soil excavated from the swale. Swales can be designed as single channels or connected in a series to increase their water distribution and infiltration capacities. The addition of check dams for swales on sloping sites can further enhance their infiltration capacity. Swales slow stormwater while diminishing its volume, simultaneously improving water quality through vegetative and soil filtration.

There are two basic types of swales, **on-contour** swales and **off-contour** swales. Detailed descriptions and applications for each type are listed below.

- ***On-Contour Swale*** **-** On-contour swales are constructed parallel to the site elevation contours as depicted in Figure 58.

  Siting: On-contour swales are suited to small and large drainage areas with gentle to steep slopes, such as open spaces, parks and landscaped areas. Swales should be constructed at least 10 feet away and downslope from building foundations. They are not appropriate for use in drainage channels, on fill areas or on sites with extremely sandy soils that may erode even at low-water-flow velocities.

  Construction: Swales should be sized to convey both smaller flows at speeds that facilitate stormwater cleaning and infiltration functions as well as peak flows without damage to the berms and spillways. Swales should be as long as possible to increase the time water is held, maximizing water quality improvement and infiltration. Water travelling in the swale should move at speeds less than or equal to 1.5 feet per second for the water quality design storm level, and less than 5 feet per second (or the erosive velocity of the channel) for the peak flow design storm level. The swale's water storage volume should be based on the amount of runoff coming from watershed above the swale and the slope at the swale location (See "“Appendix B. Pre- and Post-Development Calculation Worksheets”).

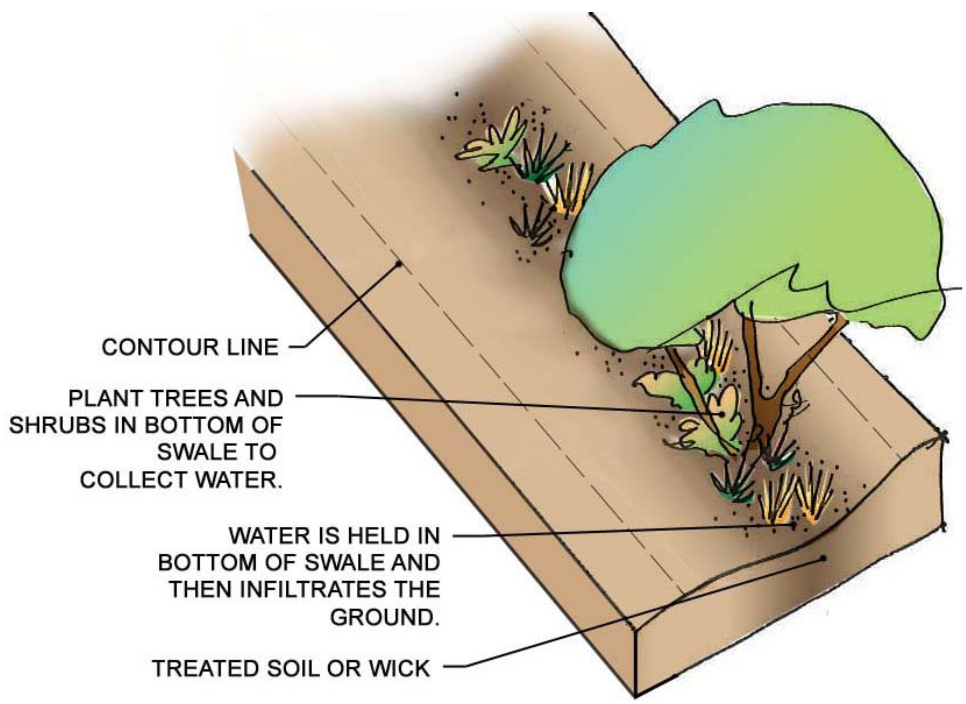


Figure 58. On-Contour Swale

- To construct a swale, dig a curvilinear depression parallel to the selected line of elevation (contour), placing the excavated dirt on the downhill side of the swale to create a berm. The top of the berm should be roughly level, except for spillway areas, which should be the lowest point in the berm and armored with cobblestone or other hard material. The bottom of the swale can be uneven as long as it is lower than the spillway,and should be mulched and vegetated. Swales should be a minimum of 6 inches deeper than the maximum design-flow-depth to prevent overflow onto adjacent areas if runoff exceeds the design size or the swale is obstructed. The swale bottom should be less than 8 feet wide to avoid erosion issues such as rilling and gullying, and should be at least 2 feet wide if the swale will be mowed.
- Smooth the swale and berm, and only compact the berm soil to maintain permeability of the swale bottom. Reinforce the berm with rip-rap or vegetation as needed, depending upon water velocity and soil types. Native vegetation that is tolerant of both drought and periodic inundation is an appropriate choice for planting in and near swales. Plants requiring more moisture should be planted on the swale sides and bottom where the soil moisture level is higher. The plants' root systems will help to stabilize the structure. Plants with an upright form will help to help slow stormwater in the swale. Plants should be placed so they do not block flows at spillway locations, and should have root structures that will enable them to withstand swale water flows. Wicks can be used to further augment the water-retaining capacity of the swales to provide for plant water needs (see additional information in the "Wicking Systems" section).
- Swales should have an internal longitudinal slope of 2% in order to convey stormwater at rates that facilitate infiltration and avoid standing water, which can create mosquito problems. Installing check dams can help to slow the movement of water within the swale to prevent erosion and to mitigate slopes in excess of 2% and up to 6% (see additional information in the "Check Dams" section).

Alternate Configurations:

- It is generally preferable to construct multiple swales at several points in the watershed versus a single large swale. On-contour swales can be built in linked series with spillways that allow overflow from one swale to flow into swales at lower elevation levels (see Figure 59). Spillways should be positioned so that the water is forced to move along the swale for as long as possible before flowing to subsequent swales. The top of the berm should be level except for spillway areas. The spillway should be lined with stone or other non-erosive materials. A rock apron or splash pad should be installed on the downstream side to absorb the erosive impact of water exiting the spillway.

Maintenance: Maintenance tasks include checking for signs of overflow following heavy rain events, and periodically removing sediment. Sediment can be removed with shovels or machinery. Reseeding or replanting may be necessary after sediment is removed.

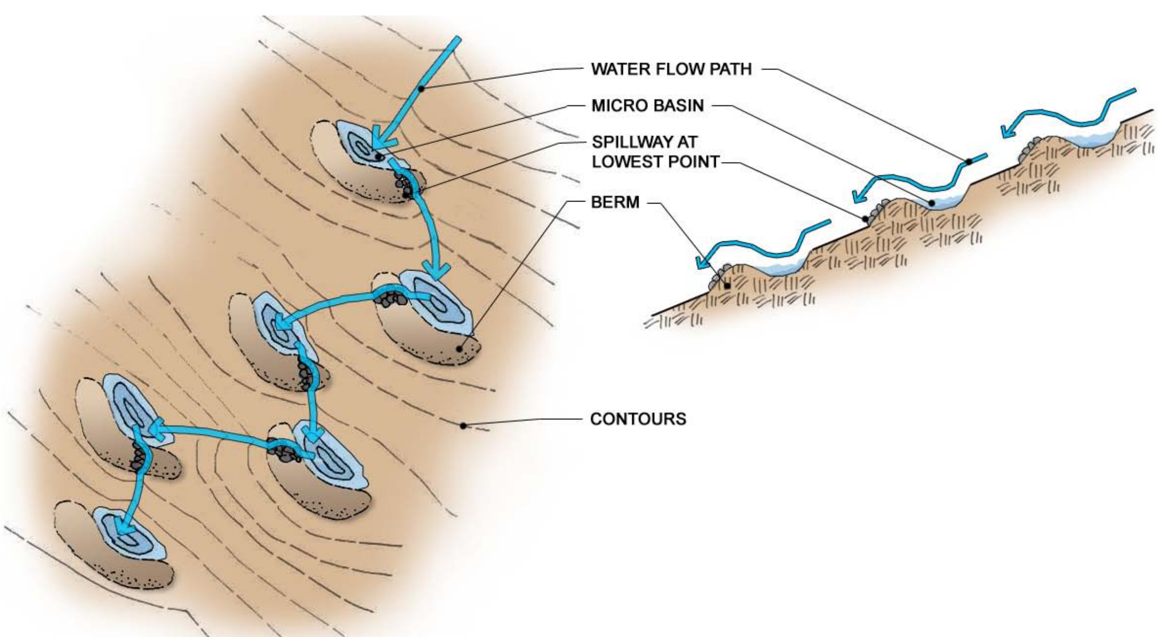


Figure 59. Linked Contour Swales

- ***Off-Contour Swale*** **-** Off-contour swales are constructed so that the swale and berm are at an angle to the contour line.

  Siting: Off-contour swales and berms are appropriate for moderate-sized drainage areas with gentle slopes, large landscaped areas and open spaces. Setting the swales at a slight angle to the contour elevation allows stormwater to move downhill slowly in a controlled manner to maximize infiltration and eventually discharge at the desired location as illustrated in Figure 60. Swales should be constructed at least 10 feet away and downslope from building foundations. They are not appropriate for use in drainage channels, on fill area or on sites with extremely sandy soils that may erode even at low water flow velocities.

  Construction: Determine the storage volume needed for the water-harvesting swale (see "Water Harvesting Calculations" in Appendix B) based upon the watershed area above the swale, the slope at the swale location and the runoff from impervious surfaces on the site. Construct a curved swale so that it is at a slight angle to the contour, with one end a little higher and the other a little lower as it follows the curve of the land. Deposit the excavated dirt on the downhill side to create a berm. Series of swales can also be constructed using a spillway to connect and allow overflow from the swale placed at higher elevations to spill into the swale at the next lower elevation. Spillways should be placed so that the water is forced to move along the contour for some distance before flowing to subsequent and downhill swales.
  - Smooth the swale and the berm, compacting only the soil of the berm. The top of the berm should be level except for spillway areas.
  - Reinforce the berm with materials as necessary (depends upon soils and velocity) using rockwork such as rip-rap. Vegetation can also be used to reinforce berms but may require the use of other reinforcement strategies as interim measures until the vegetation is established.
  - Native, drought-tolerant plants with massive and fibrous root systems are appropriate choice for planting in and near swales as they will hold the soil, reducing sediment problems. Root systems help to stabilize the structure but should be placed so they do not block spillways flows. Plants requiring more moisture should be planted in the swale on the sides and bottom where the soil moisture level is likely to be higher. Trees and large shrubs can be planted in the swale, on the berm and immediately downstream as the roots can seek moist soils.

  Maintenance: Maintenance tasks include checking for signs of overflow following heavy rain and periodically removing sediment and debris. Sediment can be removed with shovels or machinery. Reseeding may be necessary after sediment removal.

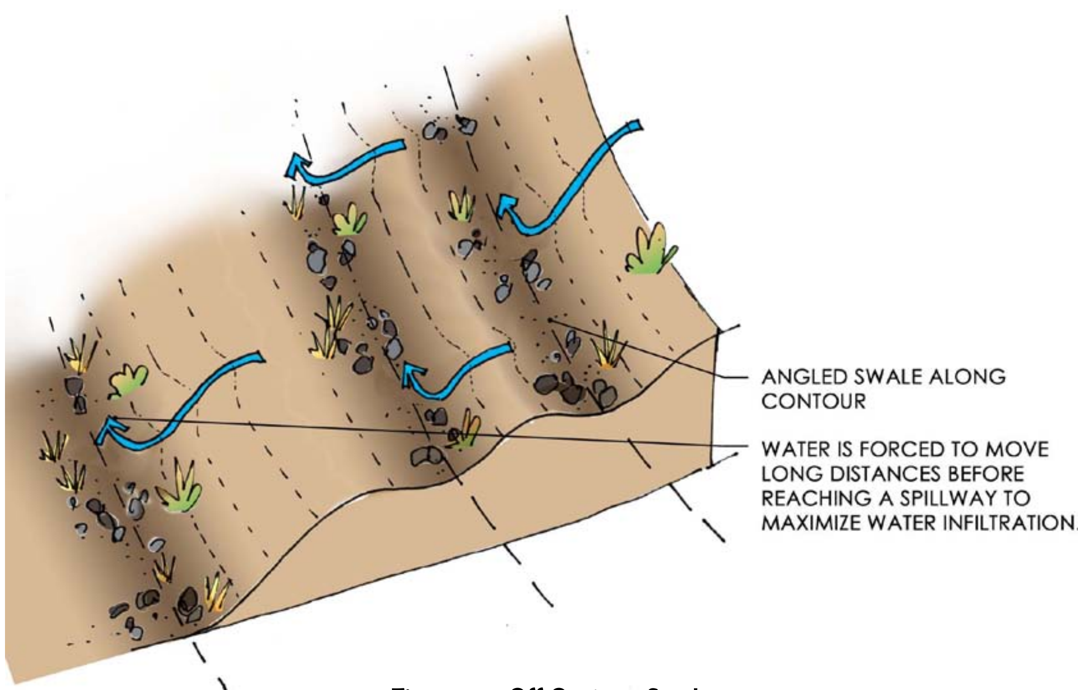


Figure 60. Off Contour Swale

Check Dams

Function: Check dams are small barriers or weirs that decrease the velocity of concentrated stormwater flows and create small ponded areas. They help to prevent channel erosion and allow suspended sediment to settle out. An added benefit is that they create excellent areas for landscaping, as the harvested water can be well-utilized. By slowing the water, the dams also promote water infiltration within the channel. Check dams also aerate runoff as it flows over the dam crest (Figure 61).

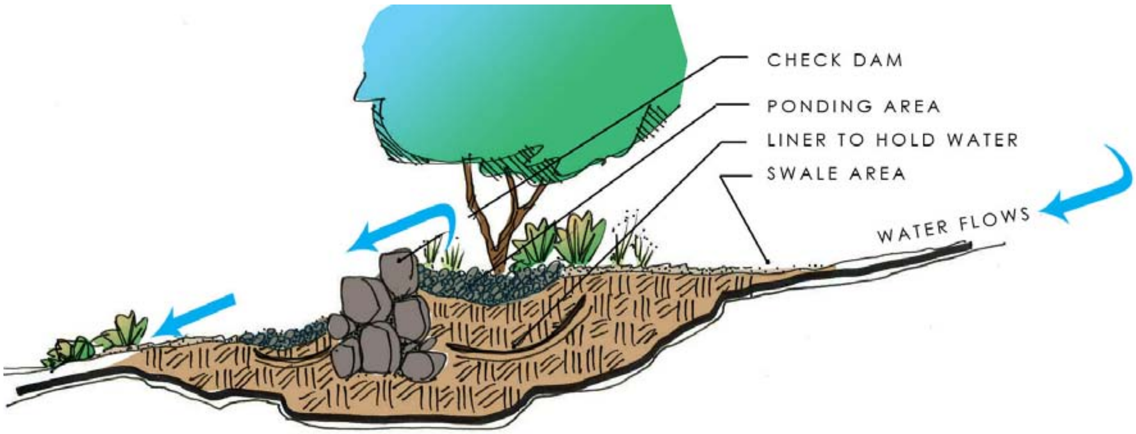


Figure 61. Check Dam

Siting: Check dams can be constructed across swales, small channels or drainage ditches. They are particularly useful for steeply-sloped swales and channels where vegetation has difficultly holding the channel banks. The total drainage area should not exceed 10 acres. Consultation with a professional engineer is advised. Check dams should not be constructed in live streams as they will disrupt movement of fish and other aquatic fauna (Figure 62).

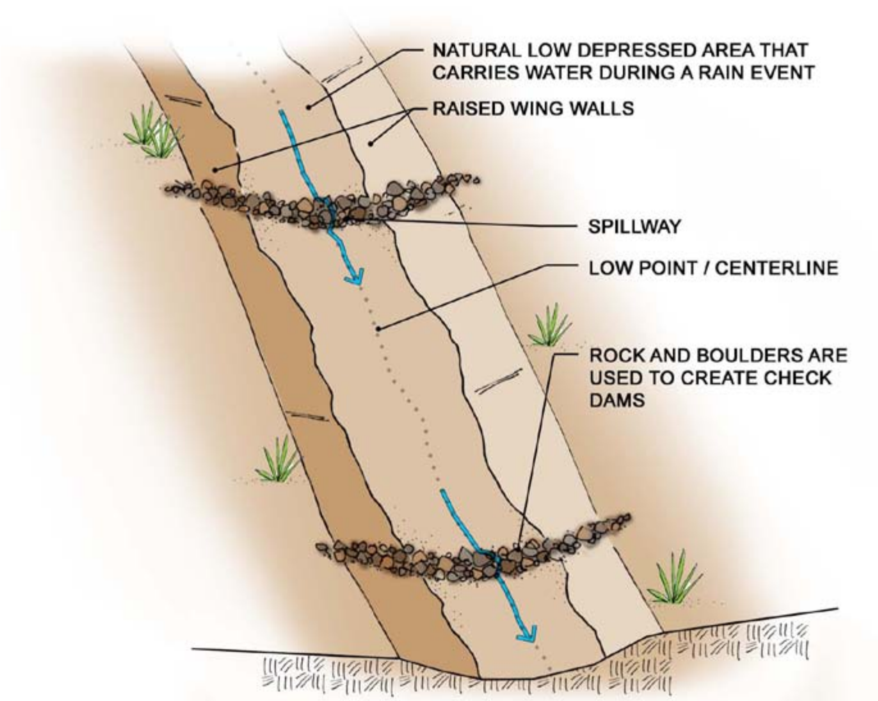


Figure 62. Check Dam Series

Construction: Check dams can be constructed from a variety of materials including logs, lumber, gravel bags, brick, concrete blocks, cast-in-place concrete, fiber rolls, boulders, cobblestone or rip-rap, all constructed in conjunction with earthen dams. The materials should be non-toxic and durable. Check dams can also be made from rock-filled gabion baskets (See "Gabions Structure" later in this chapter).

Check dams should span the swale or channel completely to avoid erosion at dam edges. The materials used should be anchored or heavy enough to resist the pressure of heavy flows. In general cobble or rocks should be a minimum 8 inches to 12 inches in size. Rock or stone can be encased in geotextile to prevent shifting during high flows. The geotextile can also be extended up and downstream of the dam to help prevent erosion on the front and rear aprons of the dam.

Logs should be 4 inches to 6 inches in diameter and embedded at least 18 inches into the soil or secured to vertical support logs that have been buried to that depth.

The center of the dam should be lower than the sloped ends of the check dam edges to ensure that water flows over, rather than around, the dam.

It is possible to use erosion control blankets, which are biodegradable open-weave blankets, in conjunction with check dams to facilitate vegetation growth on channel slopes and bottoms.

Check dams should be installed at heights and distances apart to allow small pools to form in the widened channel behind them, taking into account the length of time standing water will remain if the channel does not run between storm events. Standing water provides mosquito habitat and can kill vegetation in the channel if it remains for an extended period. In general check dams should be a minimum of 12 inches thick, as wide as the swale, and a minimum of 3 inches to 6 inches high. Check dams should be placed at every one foot drop in elevation or a minimum of 50 feet apart. For channels with steep slopes running their length, check dams should be spaced so the crest of each dam is at least as high as the toe of the next dam upstream, creating continuous ponding along the length of the channel and preventing erosive flows (see Figure 63).

Maintenance: Look for evidence of scouring, channel erosion or damage on the dam front, rear apron, or at the outer ends of the dam and repair or adjust the dam layout accordingly. Periodic excavation of built-up sediment behind the dams may be required when sediment depth reaches half the dam height. If dam materials have been removed or misplaced by high flows, replace them and consider whether the dam design should be augmented to address similar volumes and velocities in future.

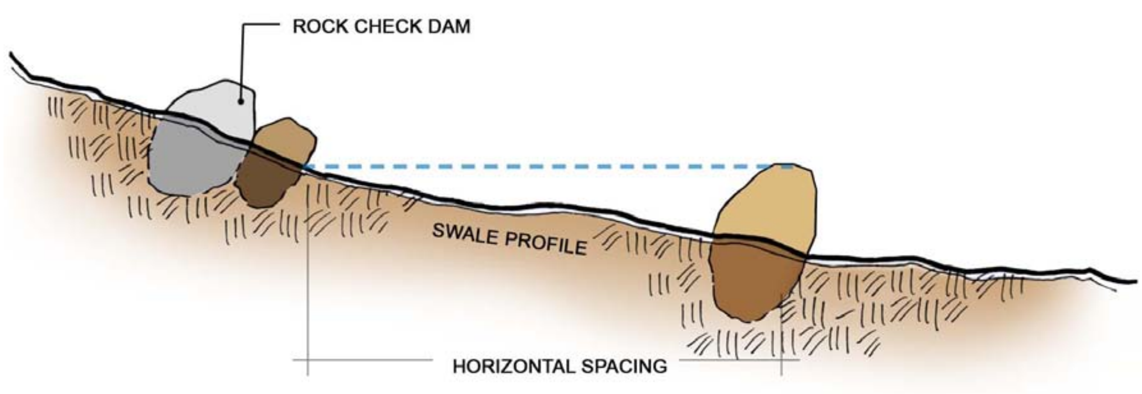


Figure 63. Check Dam Spacing

Gabion Structures

Photo 42. Gabion

Function: Gabions are semi-permeable structures that can be used to construct check dams to slow flows within water channels, or for retaining walls or channel revetment to stabilize highly erosive or steep slopes along channels. The resulting decreased water velocity helps to prevent erosion, allows sediment to settle out and facilitates water penetration into the channel and adjacent soils.

Siting: It is advisable to consult a qualified professional regarding appropriate siting and design. Gabion structures incorrectly constructed or placed can create or aggravate erosion problems and pose safety risks. Gabion walls are sometimes placed at or around curves to prevent erosion during large storm events. Erosion problems at the base and edges of the gabion wall can be lessened by providing a rip-rap apron. In smaller water channels that drain areas less than four acres, several smaller gabions constructed at frequent intervals are more effective than a single gabion greater than 3 feet in height. Channel banks at gabion locations should be firm or rocky and not sandy.

Construction: Gabions are large, multi-chambered, welded wire or wire mesh cages or baskets filled with 4-inch to 8-inch stones or other similar material that is appropriately sized to stay within the baskets. The cages are then wired together to construct flexible and permeable larger blocks which are then set in courses to build various structures. Gabion construction is simple and does not require skilled labor. Pre-fabricated gabion baskets can be purchased, or they can be custom-built. The baskets can be lined with geotextile to prevent buildup of sediment within the void spaces between fill stones; however, soil deposition and subsequent plant establishment can be desirable as it further stabilizes and naturalizes the structure. If the structure is being used as a check dam, it is important to include a downstream rock apron with a length double-to-triple the height of the gabion as shown in Figure 64. The depth of the structure should be double the diameter of the rock used in the rock apron. A minimum depth of 1 to 2 feet or a depth equal to twice the diameter of rock, whichever is greater, should be used. The apron should also span the entire width of the gabion. The apron should be encased in wire mesh and tied to the gabion in several places to prevent shifting.

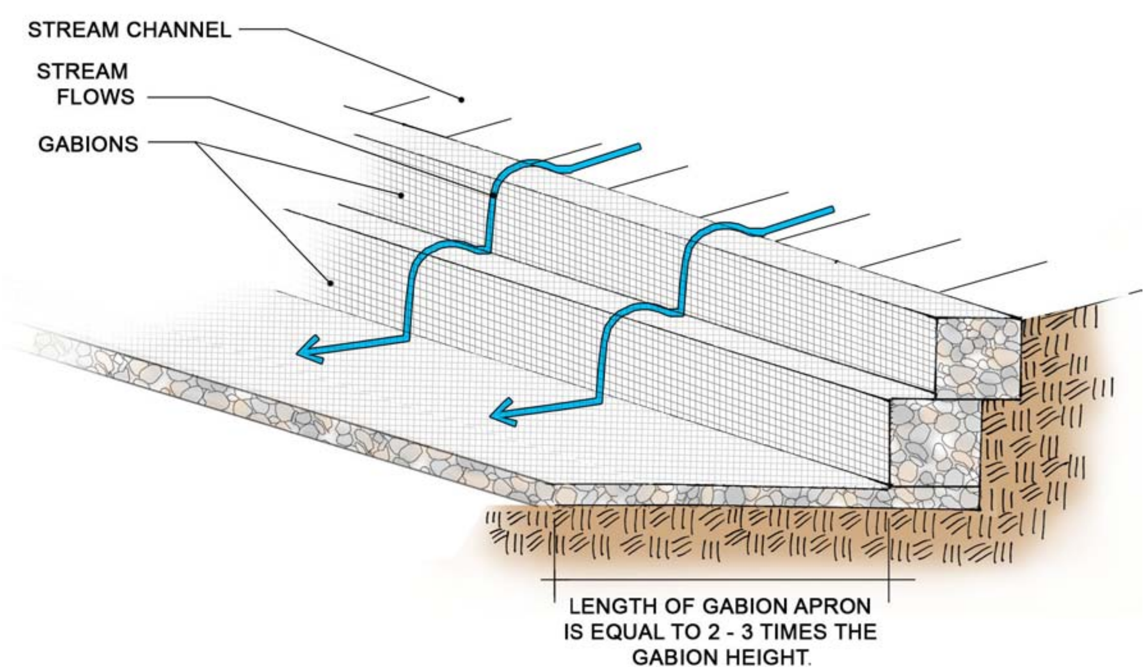


Figure 64. Gabion Structure

The wire mesh baskets are galvanized and can also be coated with PVC to prevent corrosion of the metal. Site conditions that could contribute to excessive corrosion, such as poor water quality and acidic soils, should be considered when determining whether coating is needed.

It is important that foundation surfaces are smooth and reasonably level and that the gabions are securely tied into them as well as into abutting surfaces. The baskets can be filled mechanically or manually.

Gabions should be placed perpendicular to the channel so that the water flows straight into the gabion rather than at an angle. Gabions can be placed at angle or parallel to the flow path to prevent erosion or slope stabilization problems at the banks of the channel. The gabion should be sunk 12 inches to 18 inches into the channel bottom and banks to hold it in position. The top of the gabion structure should be lower in the middle than at its edges at the channel banks to ensure that water flows in the center of the channel. It is advisable to consult a qualified professional regarding appropriate siting and design for gabion structures.

Maintenance: Properly constructed gabions are very robust structures as their permeable structure allows them to dissipate the energy embodied in stormwater flows. The porosity is useful in retaining wall applications as the voids allow evaporation and drainage to remove excess moisture from the backfill. When correctly built and sited they require very little maintenance. Periodic inspection is advisable to confirm baskets are intact and to look for evidence of undercutting or excessive erosion at transition areas. If such evidence is found, adjust the gabion or apron dimensions to correct the problem.

Curb Cuts

Function: Divert stormwater from paved surface and direct it into landscape areas or conveyance devices.

Siting: Can be used to divert stormwater into parking lot islands or other adjacent landscape areas and to direct water into medians or landscape areas along roadway edges.

Construction: There are several types of curb cuts, such as simple openings in a standard concrete curb (Photo 43), or one with additional features designed to facilitate, slow and direct flows (Photo 44). In some cases it is also possible to eliminate curbs by sinking parking island areas and installing car stops with perforations (Photo 45). In all instances, inflow areas should be protected from erosion by installing boulders, rip-rap, cobble, landscape fabric or similar materials.

Maintenance: Monitor openings to remove trash and debris. After storm events check for evidence of erosion and, if present, add materials to prevent further degradation.

Photo 43. Curb Cut

Photo 44. Modified Curb Cut

Photo 45. Curbless Option

Roof Drainage

Roofs are designed to shed rain in order to protect buildings from damage. In conventional designs, the water that falls on roofs is conveyed away from building foundations, then flows to the storm drain. Roof drainage can be captured and used on site through a variety of water-harvesting systems. The first components in such a system are the gutters and downspouts that collect and move the water down to the next component. As a general guideline, gutters should be at least 5 inches wide and should be composed of galvanized steel, aluminum or other non-corroding material. The front of gutters should be 1/2-inch lower than the back. Gutters should slope along their length at rates of 1/16-inch per foot for sectional gutters and 1/16 inch per 10 feet for seamless gutters. Consulting a company that specializes in gutter design and installation is advisable to ensure gutters are appropriate for the roof type, potential snow load and other factors.

Photo 46. Rain Chain with Rain Barrel

Downspouts should be spaced 20 feet to 50 feet apart and should be provided at a rate of one square inch of downspout area for every 100 square feet of roof area. Downspouts should direct water into the landscape or water storage devices such as rainbarrels or cisterns.

Rain chains or open canales can be used in place of downspouts to direct water to storage devices (Photo 46), or to conveyance devices such as gutter extenders or swales that divert it to landscaped areas. The various devices can be used alone or in combination; for example, rain chains and rain barrels could be used for individual units of an office complex or small apartment units. Large structures with vast areas of impermeable surfaces will require more complex site drainage systems with greater storage and infiltration capacity.

Photo 47. Roof Drainage using Canale Beams

Photo 48. Interior Crickets for Canale

Infiltration Devices

The water-harvesting methods described below are all types and scales of basins designed to collect, slow, and allow storm runoff to infiltrate into soils on the site. Water catchments and infiltration devices should be located at least ten feet away from building foundations and can be integrated into the landscape design.

Microbasins

Function: Collects and retains stormwater in localized basins.

Siting and Water Volume: Microbasins can be used to collect runoff from smaller areas with gentle slopes or from relatively flat land with low volumes of stormwater runoff. They can be built in a variety of sizes to support the differing water needs of single or multiple plants. In parking lots, planter areas can be designed to harvest runoff that comes through curb cuts (Photo 49). Microbasins are not appropriate for use in locations with heavy stormwater flow such as arroyos or washes. The scale of the basin must be based on site-specific conditions and potential stormwater flows. A series of basins with spillways connecting them can be constructed to address areas with more concentrated runoff; however, this approach requires consulting an engineer. Microbasins should be designed and constructed to capture and infiltrate stormwater quickly enough to avoid mosquito problems. Bernalillo County Ordinance, Chapter 38. Article III. Division 3 Design Standards requires that retention ponds drain in 24 hours or less, with some exceptions.

Photo 49. Parking Island Microbasin

Construction: Microbasins can be constructed in a variety sizes and configurations, individually or in a series. Type and configuration options include:

- ***Localized Depression*** **-** This is the simplest form of microbasin, comprising a depression without berms (Figure 65). A variation of this type of basin would be depressing the interior of a parking island within a curb. Water collection potential could be further augmented by curb cuts.

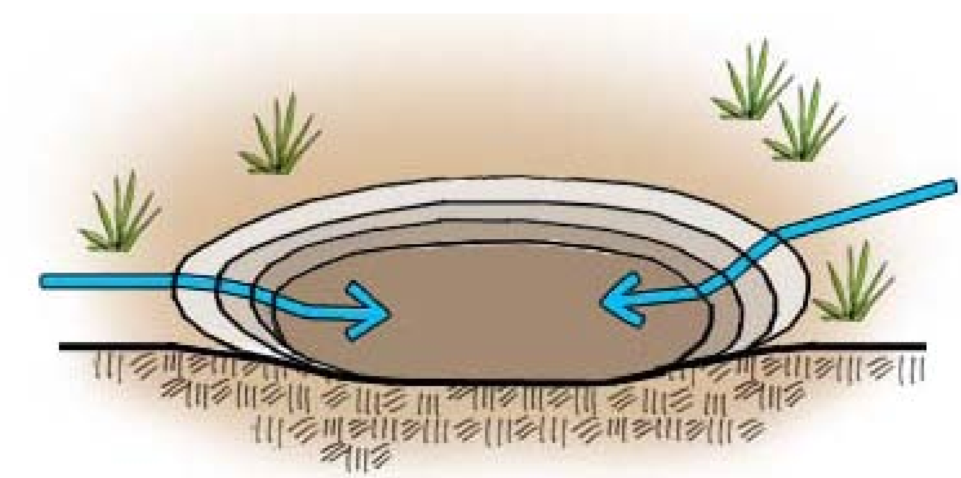


Figure 65. Localized Depression

- ***Eyebrow* -** Dig out a depression (basin) and deposit the excavated dirt downhill and on the sides of the basin to create a thick, gently sloped berm in the shape of a crescent pointing away from the water entry point as shown in Figure 66. A spillway to direct overflow can be created with an armored depression at the desired point along the berm. Compact the berm to help prevent it from eroding. The berm can also be armored with rip-rap or cobble or planted to further prevent erosion. Planting selections should consider conditions in the basins, such as the potential for temporary flooding in the bottom. The bottom of the basin can be flat or concave to concentrate water at the desired location or to provide even more infiltration across an area. Flatten the bottom of the basin without compacting. Microbasins should also be mulched and planted to facilitate rapid water infiltration.

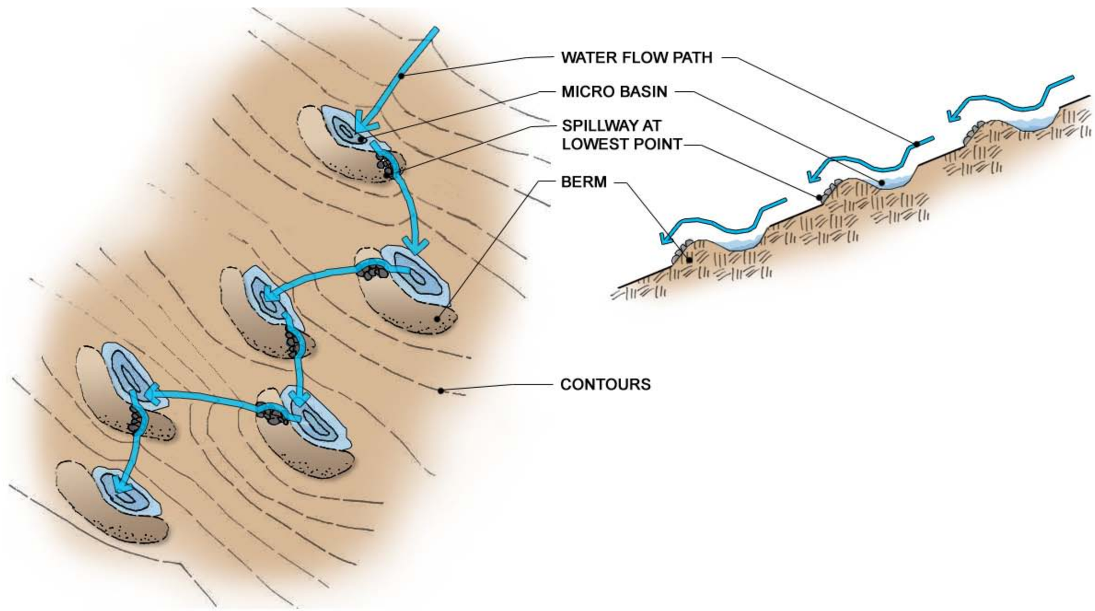


Figure 66. Eyebrow Microbasins

- ***Series* -** Microbasins can be constructed in a series to address moderate flows. Placing them in an offset path relative to each other lengthens the flow path and affords additional opportunity for infiltration. Spillways should be constructed as noted previously to direct overflow from one basin to the next.

- ***On-contour Series* -** Microbasins can be constructed in series along one or both sides of a ridge or elevated area to capture and infiltrate runoff. The basins should be placed to follow the contour line around the ridge, with their upslope ends at the same elevation. The same principle can be applied to collect runoff from elevated surfaces such as sidewalks (Figure 67).

Maintenance: Monitoring is critical. Microbasins should be checked following large rain events for evidence of overflow, which can indicate the need for adding or adjusting a spillway. If the basin is appropriately sized, sited, and constructed, overflow should rarely occur, with the exception of series basins that are designed to overflow into one another.

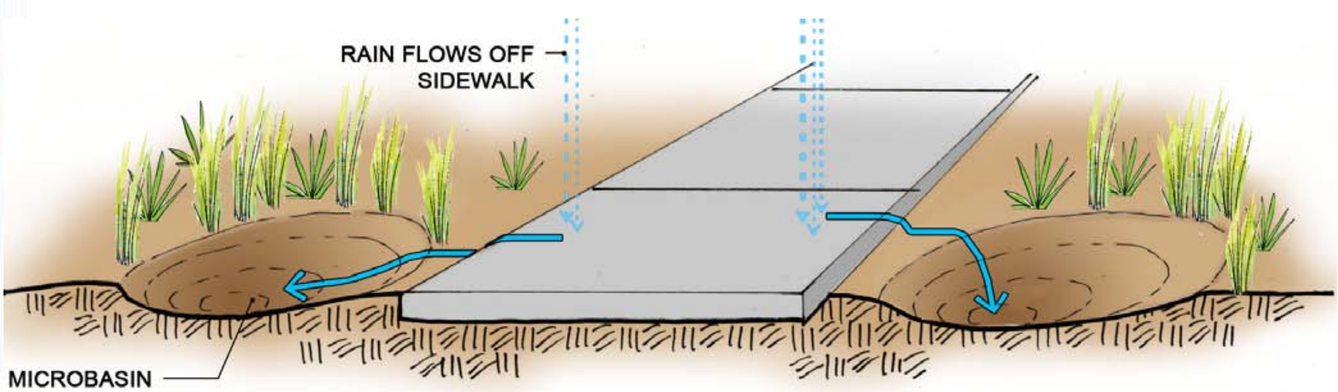


Figure 67. Microbasins along Sidewalk

Soil Imprinting

Photo 50. Soil Imprinting

Function: Imprinting roughens the land surface to increase its water-holding capacity, which facilitates increased infiltration of precipitation. The imprints funnel water into depressions. Water, seed, plant litter and topsoil mix together at the bottom where they help to germinate seeds and establish seedlings. Seedlings in the imprints are protected from drying winds and sunlight, providing increased germination and survival rates.

Siting: Imprinting is appropriate for reseeding areas that have compacted or degraded soils. It can be used on flat or sloping areas.

Construction: Imprints are formed by running a roller with angular steel teeth over the target soil surface. The steel teeth form troughs or indentations by compressing and shearing the soil, as well as crests or ridges that are lifted between the troughs. A well-designed imprinter produces these two interacting features with minimal soil disturbance or compaction.

Maintenance: Depending on the site conditions, imprinting and seeding, may need to be repeated over a period of several years to achieve the required revegetation density.

Waffle (or Grid) Gardens

Function: Creates a series of square or rectangular depressions laid out in a grid (similar to a waffle) which collect and infiltrate water to support plant material requirements.

Siting: Waffle gardens can be used on flat or sloping terrain so long as the waffle basin bottoms are relatively level. This distributes water evenly and prevents it from accumulating in one area of the waffle or eroding the waffle wall.

Construction: Create small depressions either by excavation or by building up small berm walls between waffle basins. To work well, the waffle depressions should extend at least partially below grade to abate subsurface migration of water. Once they are planted, mulch the basins to increase moisture retention.

Maintenance: Re-excavate waffle basins as needed to ensure sufficient depth for water collection. If basin bottoms become compacted, amend soil or aerate to increase permeability.

Permeable Paving

Function: Porous, pervious or permeable pavings allow stormwater and air to filter through them and infiltrate the soil below, reducing stormwater runoff. Some pollutants are also removed. Permeable pavings can be used alone or in conjunction with sub-surface storage or water treatment devices such as vault reservoirs. Permeable pavings come in a variety of materials and can be used for a range of applications including parking lots, sidewalks, driveways, plazas and courtyards, tennis and basketball courts, bicycle trails, fire lanes and low-traffic roadways. The use of pervious paving can save money by reducing stormwater impact fees and the amount of land dedicated to stormwater retention or detention areas. Paved surfaces play a major role in transporting stormwater runoff and contaminants to receiving waters. Permeable paving can be used to infiltrate stormwater and reduce the amount of runoff leaving the site, helping to improve runoff quality and decrease downstream flooding. Using permeable paving materials reduces the effective imperviousness of the site while maximizing land use. Permeable paving also has the potential to reduce or eliminate the requirement for conventional stormwater retention/detention systems and sewer pipes.

There are several types of commonly available permeable pavings:

- ***Permeable concrete and asphalt*** are similar to standard concrete and asphalt, but are open-graded, meaning the aggregate is of a consistent size with no fines, or small particle, content. A special binder is frequently included in the material mixture as well. The open-graded aggregate creates void spaces throughout the paving material which allow water and air to pass through it and into the ground below. Methods for installing permeable pavements differ from the standard, impervious types. Most permeable paving systems have an aggregate base to provide structural support and act as a base reservoir to provide runoff storage and remove pollutants through filtering and adsorption. Well-constructed porous pavements have the capacity to meet or exceed a site's pre-development infiltration level.

  When properly installed, **permeable concrete** contains 15 to 30 percent void space throughout its entire volume which allows water to drain through to the soil below (Photo 51). The void spaces increase in size from top to bottom of the concrete's cross section, reducing the chance of clogging. Potential flow rates through pervious concrete range from 140 inches per hour to more than 1,000 inches per hour. An additional benefit of pervious concrete is its performance during precipitation and freezing events. The moisture does not remain on the surface but instead moves down into the voids and base course reservoir, providing a safer driving surface. As an example, a 1-inch-by-1-inch by 6-inch deep column of permeable concrete can store 1.5 inches of stormwater. The voids also harbor beneficial bacteria, which help to break down pollutants such as hydrocarbons. The cement-based concrete does not leach harmful chemicals, though it can slightly impact the pH of soil it contacts. Pervious concrete can also reduce the heat island effect as it can be as much as 12 degrees cooler than conventional pavement. Porous concrete can be constructed to a range of load-bearing strengths but when used for roads is generally restricted to lower and lighter traffic loads.

Photo 51. Permeable Concrete

  Porous asphalt surfaces are used on highways and other roads to improve driving safety by removing water from the surface. It can also be used for jogging paths, bike trails and similar applications. Porous asphalt does present some potential issues that should be taken into account, however. Asphalt is oil-based and can leach toxins, which can be carried into the receiving soils along with infiltrating stormwater. Healthy soils can remediate some of these toxins, but care should be taken to ensure adequate remediation capacity exists to prevent problems. Another consideration is the potential for "drain-down" that can occur when porous asphalt is exposed to higher temperatures such as during New Mexico summers. Drain-down happens when the asphalt binder migrates downward through the asphalt's void spaces due to heat and gravity. As the softened binder flows downward, it carries particulate matter such as sand and dust from the surface until it encounters a cooler area. The binder then fills the void spaces at that level and hardens. Over time drain-down can greatly reduce or eliminate the asphalt's permeability. At the time of this writing, the only solution is to replace the asphalt.

- ***Open-jointed pavers*** can be made of concrete or stone and are laid with open, permeable spaces between the pavers. The built-in drainage spaces can be filled with rounded gravel or a well-draining soil mix and planted with grass or groundcover. These pavers are not as structurally stable as interlocking pavers and so are appropriate for slower speed and lower weight traffic-related applications (Photo 52).

Photo 52. Open-jointed Pavers

- **Interlocking concrete or brick pavers** are precast with spacers that automatically provide a consistent drainage space around each paver. The drainage spaces can be filled with gravel or a well-draining soil mix and planted with grass or groundcover to allow stormwater to filter through to the underlying soils. Interlocking pavers are very durable, require minimal maintenance and have heavy weight-bearing capability. Interlocking pavers may in some cases be placed over a stone reservoir base to increase water detention and infiltration capacity. An additional advantage of pavers is their ability to be reused.

Photo 53. Interlocking Pavers

- **Grass paving grids** (also called reinforced turf) are composed of a flexible grid of plastic rings placed over a base course that is usually a blend of gravel, sand and topsoil when topped with turf. The ring grid is filled with topsoil and planted with grass or a groundcover. Grass paving grids are appropriate for low-speed, low-traffic-frequency areas such as overflow parking, residential driveways and fire and maintenance access lanes.

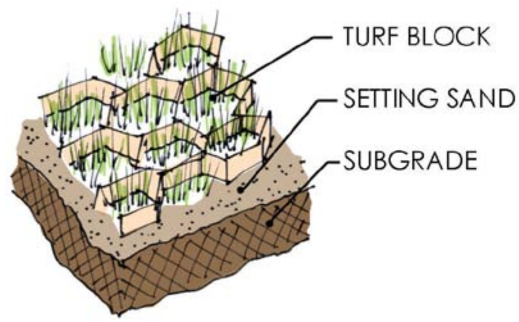


Figure 68. Grass Paving Grid

- **Gravel pavers** are based on the same flexible plastic ring grid as grass pavers but are placed over a geotextile and filled with gravel, which provides increased load-bearing capacity compared with grass pavers. Potential uses for gravel pavers include any low-speed, high-frequency traffic areas such as parking lots and vehicle storage yards, service yards or outdoor bulk storage areas. The ring grid structure of grass and gravel paver systems, along with the base course layer, distributes loads and help to prevent soil compaction and erosion. These paving solutions also help to reduce heat island impacts. In addition, the ring grid system is frequently manufactured from post-consumer recycled plastic.

- **Crusher fines** are a mixture of aggregate and small stone particles, typically 3/8 inch or less, and are available in a range of colors. Fines with no binder added are appropriate for low-use walkways or trails. With the addition of binding agents such as polymers, resins or plant-based binders such as psyllium, **stabilized fines** can be used for higher-use walkways and trails, as well as areas such as outdoor break rooms or recreation areas. An advantage of fines is ease of maintenance; they require only raking and compaction and periodic replacement of displaced or degraded material. Fines also contain no oils or toxins that could leach out, and depending on color, can have a lower heat reflectivity level than other regular concrete or asphalt. Fines provide a more cushioned surface for running and mountain biking than concrete or asphalt and are less expensive than those materials.

- **Single-sized aggregate**, such as loose gravel or stone-chips without any binder, is a highly permeable and relatively inexpensive paving option appropriate for low-speed, low-traffic settings such as car-parks and driveways.

Siting: Generally permeable pavings should be placed at least 3 feet to 4 feet above the level of the seasonal high-water table to avoid water ponding within the paving or base course material and potentially causing damage. Permeable pavings also generally require either well-draining subsoil (sandy soil or sub-grade treatment) to provide sufficient temporary storage space to allow water to infiltrate the receiving soil. The infiltration capacity of the underlying native soil is a critical design consideration for determining the necessary base course depth for stormwater storage and for determining whether an under-drain system will be required. The paving design should infiltrate the design storm runoff into the underlying soil within 24 to 48 hours. If the subsoil is composed predominantly of clay, silt or other expansive soils, care should be taken to ensure the paving design will drain and infiltrate water effectively within the required timeframe. If the underlying soil type does not allow for complete infiltration within that timeframe, modifications such as an overflow drainage pipe, increased the subbase storage capacity, or water draining to alternative temporary storage and infiltration devices may be required. **Fines and aggregate pavings** should be applied on slopes greater than 6% to avoid loss due to surface runoff erosion. When placing fines on expansive or hydric soils such as clay, use of filter fabric is advisable to avoid saturation and surface-cracking. **Permeable concrete, asphalt and some pavers** are laid over a rock base course that has large void, or pore, spaces. The base course supports the pavement and acts as a reservoir, holding stormwater until it can infiltrate the native soil below, or in systems with under-drains, slowly be released to the storm drain system. Highly permeable soils, such as sandy soils, have the greatest load-bearing capacities. The lower capacities of other soil types can be offset by the design of the base course underlying the permeable pavement. Care should be taken to avoid placing permeable pavings in locations where they will be subjected to large amounts of sediment being deposited by wind or water onto the paving surface. This can clog the pore spaces and inhibit drainage and infiltration over time. Such issues can be mitigated through use of other water quality devices such as filter strips, which help to reduce the amount of sediment in stormwater flowing onto the paving. Always follow manufacturers' recommendations for siting and installing manufactured paving materials.

Construction: The general construction steps for permeable pavings are listed below. Detailed design and construction specifications are commonly available for manufactured pavers and paving systems.

Permeable pavings are composed of the surface material, either permeable paving or pavers, laid over a storage layer, which is usually a coarse stone aggregate topped by a layer of smaller aggregate. This acts as a choker course, separating the surface material from the storage layer. The aggregate layer may be wrapped in non-woven geotextile. The geotextile keeps soil from clogging the storage layer.

The depth of the rock or gravel subbase should be based on the weights, frequency and speeds of the traffic it will carry, the infiltrative speed and capacity of the underlying native soils, and the amount of stormwater to be handled. An under-drain system can also be used to connect to the storm drain system to address runoff in excess of the soil infiltration and storage reservoir capacities.

Additional factors for consideration include winter conditions, such as numerous freeze-thaw cycles that may dictate increased base thickness to protect the permeable paving from heave damage.
The basic steps of the construction process are excavation, subbase installation, and finally overlay of the selected permeable paving. If a turf or gravel paving system is being used, the voids in the paver grid are filled with the relevant material (topsoil and turf, loamy sand, pea gravel, larger-sized washed gravel, etc.) depending on the system's purpose and use. Permeable pavers are placed on a layer of sand that is spread over permeable geotextile fabric laid on top of the base course. The pavers are then leveled with a vibrating plate compactor, and the joints filled with sand or the appropriate permeable fill material. Whereas most paver systems can be used immediately after installation, permeable concrete or asphalt should be allowed to cure according to the installer recommendation (usually a few days). Grass pave systems require sufficient time for the plant material to establish before receiving significant traffic.

Crusher Fines pavings should be compacted in moist (not wet) fines in 3-inch to 4-inch lifts with a vibrating plate. It is possible to add a subbase of 3/4 inch rock wrapped in filter fabric (like a burrito) in areas with drainage issues. Use of a geo-web product in addition to commercially available binders will further stabilize the fines. The surface of the pathway or trail should be sloped or crowned 3% to 5% to ensure positive drainage.

Maintenance:

- **Grass and gravel pavers.** Require minimal maintenance to ensure good infiltration. Keep the paver surface clear of organic materials (leaves, grass clippings, etc.). Periodic vacuuming or low-pressure washing should be used to clear out voids. The required frequency should be based on site conditions. Gravel fill may also need to be added after cleaning gravel pavers. Grass pavers require watering and mowing like any turf system. If the paver area will be subject to snow removal, care should be taken to lift the plow to clear the grass or gravel surface. Avoid using sand, salt, ash or other chemical de-icers as they may clog the paving pore spaces.

- **Permeable concrete and asphalt.** Need to have the surface kept clear of sediment, dirt, sand and organic debris to avoid clogging the pore spaces. With New Mexico's high winds and sandy soils, also include a minimum cleaning frequency. The maintenance considerations for permeable pavers are similar to other permeable pavements but care must be taken when vacuuming the space between pavers so that small drainage aggregate is not removed; this can cause clogging problems downstream. Periodic vacuuming is recommended to clear out voids and extend the functional life of the paving, with the frequency based on site conditions. During winter avoid using sand, salt, ash or other chemical de-icers as they may clog the paving pore spaces.

- **Crusher fines.** Require surface repairs to be done as needed, based on compaction and wear, generally every couple of years. Edges of paths or trails may also require weed removal. Hardeners should be reapplied to **stabilized fines** on an as-needed basis.

- **Single-sized aggregate.** Simply requires replenishment as needed.

Water Quality Improvement Devices

Bioretention Cell or Basin

Function: Bioretention basins are shallow, landscaped depressions or basins used to slow and treat on-site stormwater runoff. Stormwater is directed into the basin and filtered through the basin soil and plants. The cleaned water then infiltrates underlying native soils or can also be used with conveyance or storage devices as part of a stormwater treatment and infiltration system. In addition to stormwater control and filtering functions, bioretention cells can help to address on-site erosion issues and provide habitat for birds and insects.

Siting: Bioretention basins are appropriate for residential, commercial and industrial sites. Potential locations include median strips, plazas and parking lots as well as other areas on the site. The drainage area feeding the basin should not exceed two acres in size and should not contain significant sediment. If surrounding areas will contribute significant amounts of sediment, the basin should be designed with water quality improvement devices such as vegetated swales or filter strips for pretreatment to reduce sediment loads to acceptable levels. The pretreatment devices should be selected based on site conditions and constraints. Areas feeding the basin should have a minimum slope of 0.5% for paved areas, and 1.0% for vegetated areas in order to maintain water flow into the basin.

Construction: Bioretention basins typically include several key components: the contributing drainage area; any pretreatment devices; the ponding zone; a layer of mulch, vegetation and engineered basin soils; a storage layer; and an underdrain system to address excess runoff that cannot be infiltrated as quickly as needed. The ponding zone should be 12 inches or less in depth with side slopes of 2:1 or less, and should drain within 24 to 48 hours. If the infiltration rate of the underlying native soils is less than 3.6 inches per hour, a 3-inch layer of sand mixed to a depth of 2 inches to 4 inches with native soil, topped by a storage layer of uniformly-sized, washed gravel or stone, should be added to facilitate infiltration. For locations with extremely dense, low permeability soils such as caliche, greater measures may be necessary. The depth of the storage layer should be based on storage capacity needed to address runoff and should not exceed 48 inches. An under-drain pipe with a 6-inch minimum diameter should be installed at the top of the storage layer and should include a clean-out for maintenance. The under-drain should be wrapped in a filter sock to prevent clogging and should discharge into a stable infiltration outlet such as a swale, or into the storm sewer system. Compacting basin soils during construction should be avoided to achieve maximum infiltration rates. The engineered basin soil mixture can be structural soil or a mixture of sand, compost and topsoil. This should be premixed and placed in 12-inch-deep lifts. A layer of permeable geotextile or a 2- to 4-inch layer of pea gravel should be placed below the engineered soil mixture to prevent it from permeating and clogging the storage layer. Plants should be selected for their ability to deal with basin drought and flood conditions. The mulch should be permeable but large enough to avoid excessive floating and should be installed in a 2- to 3-inch layer after planting is completed.

- **Tree box filters** are a variation of bioretention cells placed in sub-grade containers containing trees. They are used in urban streetscapes and parking lots to capture and treat runoff by removing pollutants as the runoff filters through the box soil media. The runoff also provides irrigation to the tree or other plant material in the box filter system. The basic components of a box filter system are a container filled with a highly permeable bioretention soil mixture over a layer of gravel or crushed stone with an under-drain system that discharges either into surrounding soil or the storm system. Stormwater runoff drains directly from impervious surfaces through a filter media. Because of their relatively small individual capacity, multiple box filters are needed in the stormwater drainage area to significantly reduce peak-flow rates. Tree box filters provide a space-efficient stormwater management solution with high pollutant removal rates while providing a beneficial environment for street trees.

  Proprietary tree box filter systems are also available for purchase and can offer cost-effective and high-performing runoff reduction and water quality improvement capability.

Maintenance: Bioretention basins should be regularly inspected to insure infiltration is occurring at the desired rate and that water is not ponding in the basin longer than 48 hours. Any eroded areas should be repaired following storm events, and the drain structure should be checked for clogging. Debris and accumulated sediment should be removed annually and plant material replaced if needed. The mulch layer should also be replenished annually.

Filter or Buffer Strip

Function: Filter strips are used to slow runoff, allowing pollutants and sediment to filter out before the runoff reaches other water-harvesting and treatment measures or receiving areas. Filter strips also help to prevent sheet and rill erosion. Rill erosion results from overland flow that is focused by the soil surface roughness and creates narrow, shallow incisions into the soil. They are best suited to provide water quality improvement and infiltration of runoff from roadways and parking lots generated by lower-intensity rain events. Most higher velocity runoff from intense rain events is generally only conveyed by the filter strip, so they are often used in conjunction with other water-harvesting devices. There are a variety of filter strip types including sand, gravel, turf or grass, and vegetated filter strips. In the arid Southwest, sand or gravel filter strips are generally more viable than vegetated strips. Filter strips located adjacent to bodies of water are called buffers. In general, filter strips have a uniform, mild slope stretching downward from the surface contributing the runoff.

- **Sand or gravel filters -** To achieve maximum reduction of peak flow and stormwater runoff, it is important to locate filters in soils that accommodate infiltration and to minimize the ponding depth. Careful site analysis is required to design an effective, integrated network of these systems throughout a landscape.

  Design depends largely on the drainage area's characteristics. Under-ground sand filters are suited to urban areas with limited open space and a high percentage of impervious surface. Above-ground systems are suited to large drainage areas with adequate open space, such as highway interchanges, that have soils suitable for infiltration. Diatomaceous earth can also be used for filter strips. As with any infiltration/filtration system, when sand, gravel or diatomaceous earth filters are used in pollution hotspots or in poorly draining soils, they should be lined and outfitted with sub-drains that discharge to the surface.

Siting: Generally, filter strips are most effective on slopes greater than 1% and less than 5%. They should be at least 2 to 4 feet above the groundwater level to avoid permanently wet conditions that can breed mosquitoes and other disease vectors. Typical filter strip configurations are long and narrow, with a minimum flow path length of 15 feet to provide adequate area for water infiltration. The width of the strip should be equal to that of the contributing surface. Filter strips should not be used as paths or roadways. Additional considerations include use of de-icers or sand on the runoff-contributing surface. The former can impact the health of grass or vegetated filter strips, whereas large amounts of sand can diminish the useful life of the filter strip, requiring increased maintenance.

Construction: The filter strip should be uniformly graded with a slope between 1% and 5%, with the toe and top of slope as flat as possible to ensure even sheet flow and avoid ponding and erosion issues. If flows from the contributing area above the strip are concentrated, a level spreader may be needed to ensure even sheet flow, which is critical for correct filter strip performance. A range of level spreaders can be used, including concrete curbing or a 1-foot by 2-foot-deep gravel filled trench can be constructed to deliver even sheet flow to the filter trench area.

For vegetated filter strips, either grasses or a range of native xeric, low-growing plants are appropriate. If vegetation will be started from seed, erosion control measures should be used to protect seed and seedlings until they are sufficiently established to withstand erosive flows moving across the filter strip area. Supplemental irrigation may be required during the establishment period of vegetated strips. Adding a low, permeable berm at the downstream end of the strip can reduce the required strip width by lengthening the time runoff is in contact with the strip. The berm should be one foot or less in height and made of permeable material such as a mixture of gravel and sand. Generally filter strips are designed to address flows from smaller, higher-frequency storm events, usually one- to two-year storms. If flows from larger storm events have the potential to damage the strip, include a bypass mechanism to move those flows into other stormwater devices.

Maintenance: Check for and repair any eroded areas, such as channels formed by concentrated flows, to facilitate even flow over the filter strip area. If large amounts of sediment have unevenly accumulated, they should be removed to avoid disrupting sheet flow over the strip. Periodic re-grading and refurbishment of the upslope filter strip edge may be needed, depending on sediment deposition rates. Weed and invasive species removal, mowing, and trimming, and reseeding or replanting grass or turf filter strips may be needed if concentrated flows have eroded vegetation. Use of erosion-control blankets for repair areas can aid re-establishment. Turf strips should be mowed regularly to maintain a 3- to 4-inch grass height. Mowing should be done when the soil is dry to avoid compaction and tracking damage, which can disrupt even sheet flow and filter strip function. If vegetation is sparse or grass has not established appropriately, consider replacement with alternate species. If the filter strip design includes a gravel trench level spreader, periodic removal of sediment will be needed.

Constructed Wetlands

Function: A constructed shallow vegetated basin or series of linked basins that are permanently or seasonally flooded, constructed wetlands are extremely effective for water quality improvement through pollutant removal, and also perform varying degrees of infiltration function depending on underlying soil types.

Siting: Constructed wetlands are generally more appropriate for larger sites. They require a relatively large amount of space as well as a sufficient base flow to maintain the water level for wetland vegetation health and appropriate pollutant removal – a key consideration in the arid Southwest. Safety is a critical concern when siting and designing wetlands, and public access should be addressed with care. Constructed wetlands are especially useful for mitigating high nutrient loads in runoff from areas such as golf courses. Constructed wetlands are not appropriate for areas with steep or unstable slopes, and untreated runoff should never be directed into existing natural wetlands. Depending on the depth, volume, and discharge amounts of the ponding areas, approval from the New Mexico Environment Department may be required.

Construction: Given the complexity of constructed wetland design, seeking the services of a professional for siting, design and construction is highly advisable to ensure appropriate water quality function and to avoid potential nuisance and disease vector issues. A few construction considerations include the potential use of an impermeable liner to maintain adequate ponding levels in areas with high porosity soils, and ensuring that pipes and outlet structures are appropriately designed and constructed to prevent structural failure from water erosion of the berm or dam fill.

Storage Systems

Detention Ponds

Function: Detention ponds are reservoirs designed to reduce peak flow associated with large storm events by temporarily detaining a set amount of stormwater runoff while it infiltrates or is slowly discharged to another location. The ponds improve runoff water quality by allowing sediment particles and the pollutants that cling to them to settle out in still water. During storm events, runoff enters the pond's upstream inlet, and the heavier sediment-laden stormwater displaces cleaner, lighter water held in the pond by moving it up and out through the discharge outlet. The recently added stormwater then remains in the pond, allowing the sediment and pollutant load to settle out. Detention ponds can also help prevent channel erosion. Recent studies indicate that designs that provide detention for a period of 12 to 24 hours and are based on smaller-design storms, such as a one-year storm, are more effective for this particular purpose.

Detention ponds can take the form of dry or wet ponds or constructed wetlands. Detention ponds allow sediment particles and pollutants to settle out of detained stormwater. Dry detention ponds do not have a permanent pool and are often designed with small pools at the inlet and outlet of the pond. Detention ponds can be used to provide flood control capacity by including additional detention storage beyond the extended detention level.

Dry detention ponds can serve multiple purposes in addition to their stormwater management functions, such as being used as plazas, sports areas and park-like spaces during the dry season. They can also be designed with multiple levels to keep low-frequency storm events segregated to allow use of the majority of the pond area. In other situations they can be small oases of lush plants that can take advantage of the additional water (see Figure 69).

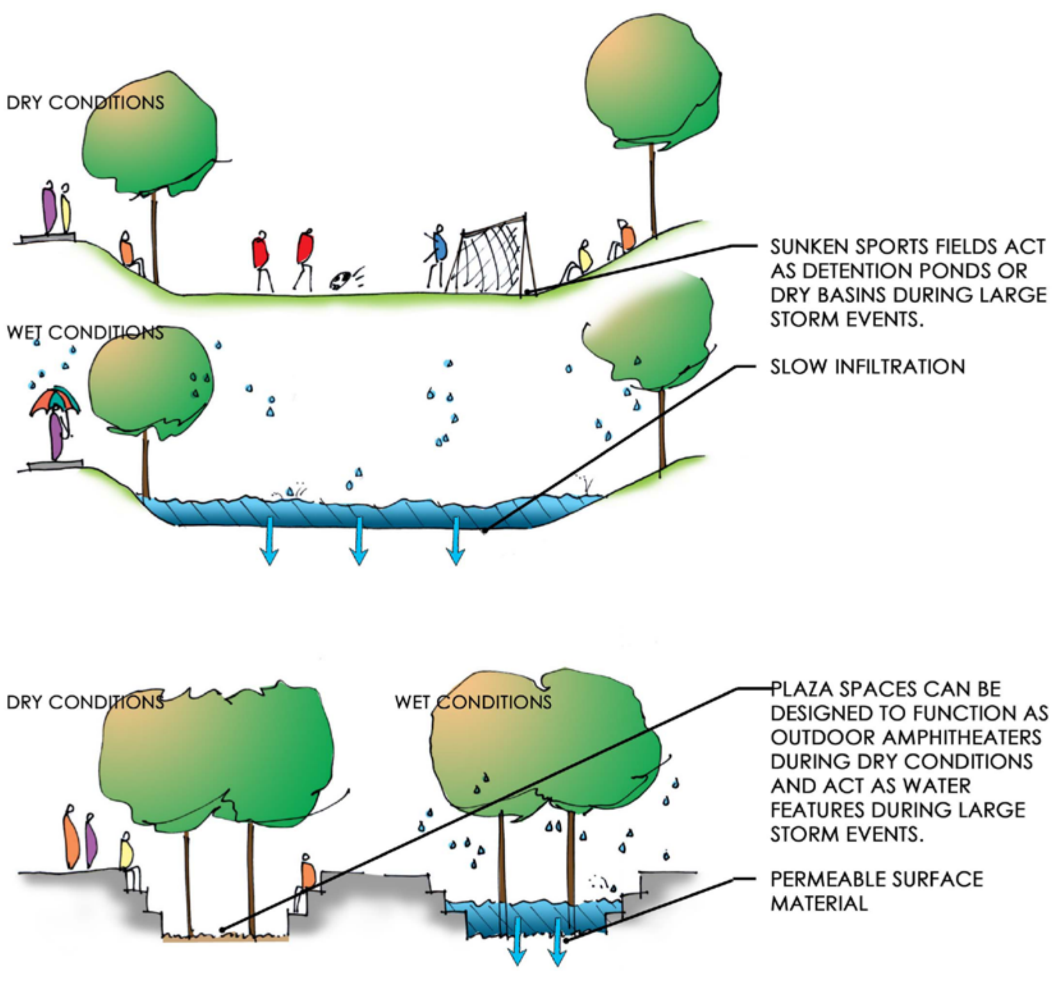


Figure 69. Multipurpose Detention Pond Areas

Detention ponds can be designed to address multiple stormwater control and quality objectives as shown in Figure 70. Detention pond outlets can be any type of conveyance device that allows water to flow out at a controlled rate. Multiple outlets can be used to address different flows from various design storm levels.

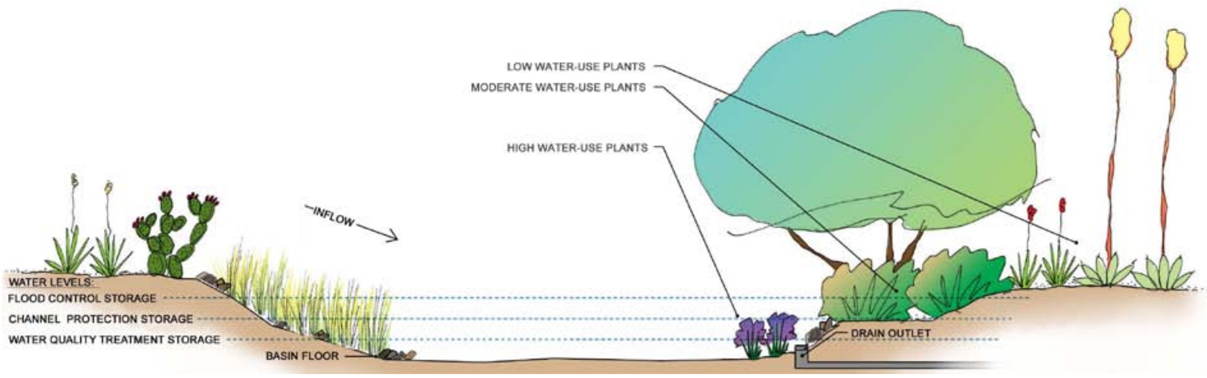


Figure 70. Detention Pond Storage Levels

Siting: Dry, extended detention ponds can be constructed on sites with stable slopes up to 15% as long as the basin bottom is relatively level. Pond drainage can be problematic in low-relief terrain areas, however. A minimum drainage area of ten acres is generally advisable for dry extended detention ponds due to pond construction costs and the potential for outlet orifice clogging. It is important to ensure that the elevation drop from the pond inlet to the pond outlet is sufficient to enable water to flow through the system. The slope of the area upon which the pond will be built should be relatively flat, and side slopes of the pond should not exceed 3:1. A minimum separation of three feet between the water table and pond bottom is recommended.

Detention ponds can be used on any soil type, with minor design adjustments needed for quick-draining soils. Dry extended-detention ponds should be a sufficient vertical distance above the groundwater table to avoid permanent wetness in the pond bottoms which can lead to mosquito issues. If the pond will receive highly-contaminated runoff from point-pollution sources, increased separation distance from groundwater will be required.

If the pond will be located on rapidly draining soils such as sand, an impermeable liner may be needed to prevent possible sinkholes or groundwater contamination.

Construction: It is advisable to consult a qualified professional when designing and constructing detention or retention pond facilities in order to ensure a safe, functioning pond that meets applicable engineering standards. Detention and retention ponds used to control stormwater runoff are required to be certified by a New Mexico licensed engineer. Pond size is driven by the desired outflow water quality level and rate, based on a chosen design-storm level. The design capacity of stormwater ponds is frequently based on 200-year, 100-year, 5-to-10-year or 1-to-2-year storms. In addition to the design-storm level, determination of the water storage volume needed for a detention/retention pond is based upon the area of the contributing watershed, amount of impermeable surface within that area, soil type, and vegetative cover (see "Appendix B. Pre- and Post-Development Calculation Worksheets"). The required pond size can be reduced by maximizing the number of on-site infiltration areas. In general, the pond's length should be greater than its width. This prolongs total detention time by maximizing the flow path, increasing filtration and infiltration. Remember, detention and retention ponds used to control stormwater runoff are required to be certified by a New Mexico licensed engineer.

A range of features can be included in the detention pond design, but basic pond design should include runoff pretreatment, treatment,and conveyance, as well as maintenance reduction and vegetation features. Pre-treatment removes larger sediment particles in a small pool called a sediment forebay before the water moves into the treatment area or main body of the pond. In the arid Southwest, a dry sediment chamber may be used in place of a wet forebay. Plants used in detention areas should be selected based on their ability to tolerate drought and flood conditions that will prevail in the ponding area. Pond design can also address periodic high-runoff volumes created by snowmelt. Vegetation for ponds handling snowmelt runoff from roads may need to be salt-tolerant. Combination retention-detention ponds have outlets that are installed at a higher elevation than the bottom of the pond so that some stormwater can be retained and the remainder can be directed to landscaping or stormwater facilities. Conveyance features to move water in and out of the pond should be designed to prevent erosion from occurring along them.

In order to maximize land use, extended dry detention ponds can be designed to serve multiple functions, such as providing a recreation or playing field area during dry periods.

Wet detention ponds generally have a primary function of improving stormwater runoff quality because they can provide significant pollutant reduction. Wet ponds must be properly designed and maintained to achieve their stormwater quality functions; it can take from three to six years to reach the ecological balance necessary to do so. During that initial establishment period, issues such as excessive algal growth and nuisance odors may occur. The design of wet ponds requires a few additional considerations to ensure appropriate function. The pond length should be three to five times its width and simply shaped to promote adequate water circulation. The permanent ponding depth should be a minimum of 3 feet—ideally 6 feet—to decrease light penetration and prevent sediment scouring. The sides of the pond should be designed with slopes that help to promote safety, minimize mosquito habitat and prevent excessive rooted aquatic plant growth, such as those in Figure 71. An underwater planted shelf around the pond perimeter can help to improve pollutant removal and prevent physical access to the deeper pond areas.

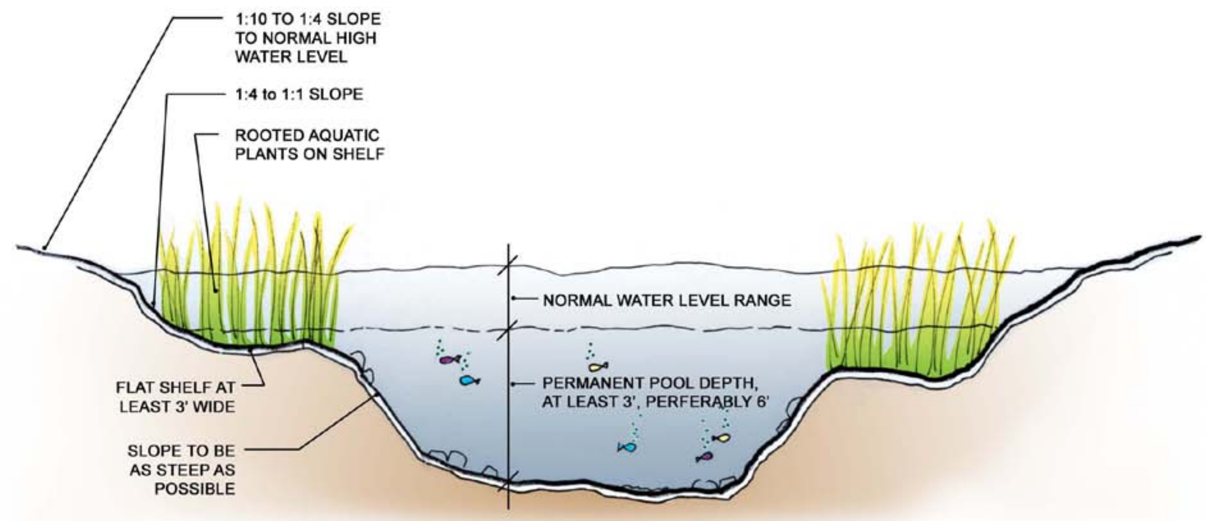


Figure 71. Wet Detention Pond

Pond inlets and outlets should be spaced well apart to avoid malfunction and designed to prevent erosion from scouring. Outlet design should maximize sediment retention during periods of low-pond depth through low-outflow volume. Inlets and outlets should be designed to prevent safety issues and an appropriately-sized emergency spillway should be included. The emergency spillway allows extreme-storm event flows that exceed the pond design capacity to safely exit the pond without causing structural damage.

If the water sources flowing into the pond are contaminated or highly polluted, preliminary water treatment devices may be needed to avoid exceeding the pond's pollutant-bearing capacity. A drain to allow pond maintenance and access routes for maintenance equipment should also be included.

Maintenance: Periodic inspection—at least twice annually—is advisable. Inspection should include a) checking for signs of bank or bottom erosion and damage to embankments, b) verifying that inlets and outlets are functioning and free of debris, and c) monitoring of sediment build-up in the pond and forebay area. If runoff feeding into the pond is high in sediment, the latter two inspections may need to be performed more frequently. Sediment should be removed when total pond volume has been reduced by one quarter. Accumulated debris or litter should be removed, dead vegetation replaced, and any erosion or undercutting damage repaired.

Wet detention ponds require periodic dredging to remove contaminated sediment. Dredging frequency can be reduced through pond design that includes excess or sacrificial volume.

Retention Ponds

Function: Retention ponds are designed to hold stormwater and allow it to infiltrate; therefore, do not incorporate outlets. These ponds can be used in conjunction with a variety of water-harvesting techniques such as swales and other conveyance devices, or can receive stormwater directly as it is diverted from a paved surface. The design considerations listed above for wet and dry detention ponds are applicable to retention ponds, with the exception of outlets; however, the design should account for emergency overflow.

Siting: Retention ponds can be constructed on sites with slopes up to 15% as long as the basin bottom is relatively level. The slope of the area upon which the pond will be built should be relatively flat, as side slopes of the pond should not exceed 3:1. A minimum separation of 3 feet between the water table and pond bottom is recommended unless the pond is designed as a wet pond.

Construction: Key objectives of retention pond design include safety, (due to the potential hazard represented by standing water), disease vector prevention (such as mosquitoes), appropriate and excess capacity management. Generally pond depth should not exceed 8 feet. It is advisable to consult a qualified professional when designing and constructing detention or retention ponds to ensure a safe, appropriately functioning pond.

Maintenance: Periodic inspection—at least twice annually—is advisable. Inspection should include checking for signs of bank or bottom erosion and monitoring sediment build-up in the pond and forebay area (if applicable). If runoff feeding into the pond is high in sediment, the latter two inspections may need to be performed more frequently. Sediment should be removed when total pond volume has been reduced by one quarter. Accumulated debris or litter should also be removed, dead vegetation replaced and erosion or other damage repaired. Verification that mosquitoes and other disease vectors are not present should also be performed, and any issues addressed.

In-ground Temporary Storage and Infiltration Systems

These comprise a variety of methods devised to temporarily hold stormwater in the ground and allow it to infiltrate. They usually employ minimal technology and can be easily installed by a landscape contractor or homeowner.

French Drains

Function: French drains are rock-filled trenches designed to facilitate infiltration of stormwater. The concept is to allow the water to infiltrate surrounding soils through the trench sides, ends and bottom. French drains can be constructed independently, as shown in Figure 72 or as part of a more complex water-harvesting network.

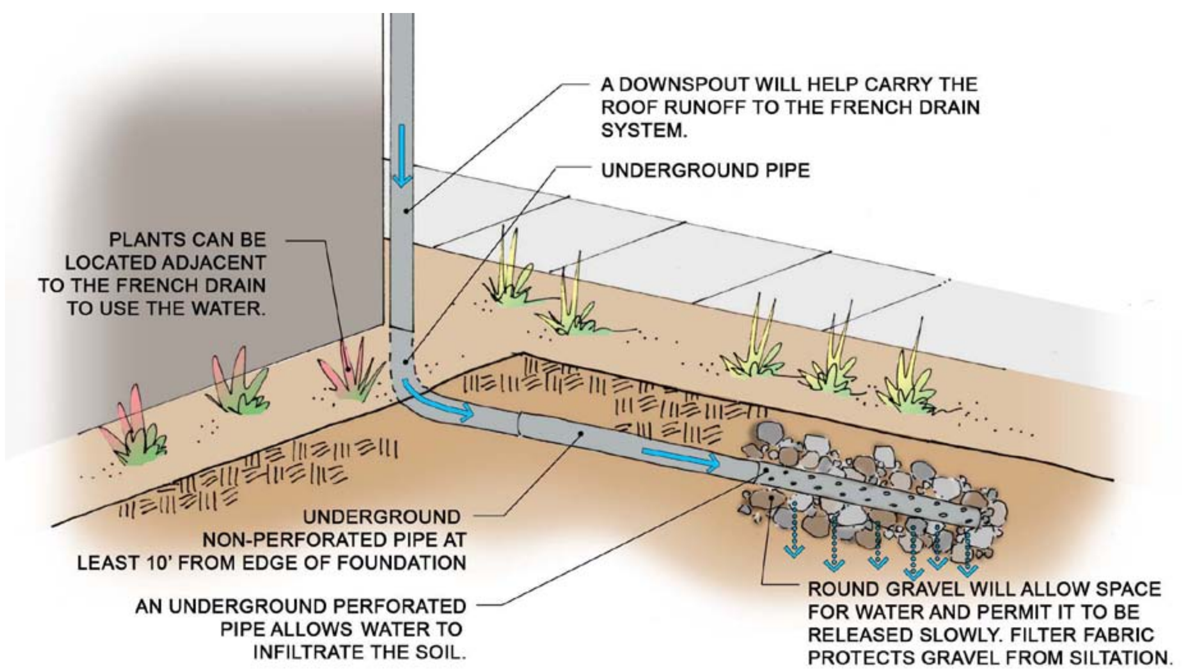


Figure 72. French Drain

Figure 73 illustrates the incorporation of French drains, swales, and microbasins in a residential landscape. When these techniques are used in conjunction with devices such as rain chains and rain barrels, they can provide 30% to 80% of the water needs for the landscape.

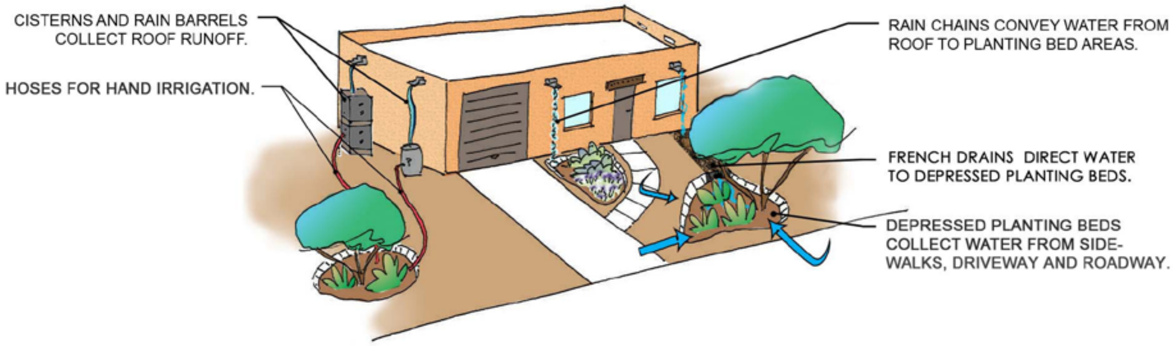


Figure 73. Water Harvesting Using French Drain, Swales and Microbasins

Siting: French drains are appropriate for low to moderate flows on flat to moderately-sloped areas and can be used in steeply sloped areas to provide greater storage volume than would be possible with surface basins.

The soil surrounding the drain determines how quickly water will be able to infiltrate. Sandy or gravelly soils drain fastest, whereas heavier, clay soils drain more slowly. Thus the soil type should be taken into account when determining the size of and location for the drain. French drains have about one-third the water-holding capacity of an open trench due to the space consumed by their rock fill.

French drains can be placed either on or across contours; either configuration can help to prevent erosion by capturing and slowing water, allowing it to infiltrate.

To avoid diminished infiltration over time, the runoff feeding into French drains should be low in sediment. If some sediment will be present, wrapping the rock fill in filter fabric or placing the drain in conjunction with filtering devices such as filter strips or microbasins can help to prevent clogging. French drains should not be placed in watercourses due to the high sediment potential.

Try to avoid placing French drains within the root zone's of existing trees as the excavation will destroy roots and could compromise the tree's health. If placing the drain within an existing tree root zone is the only or best option, orienting the drain to run radially towards the tree trunk will minimize root destruction (see Figure 74).

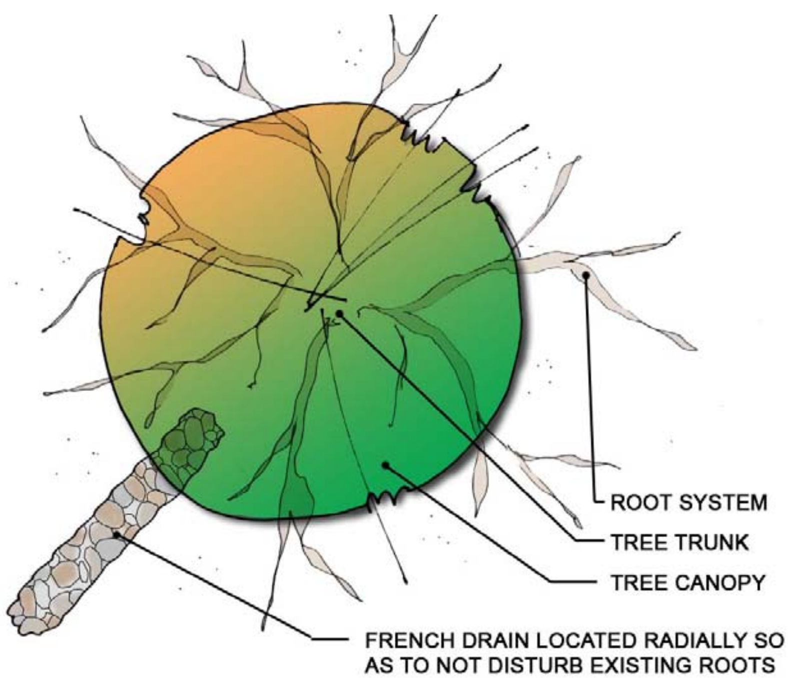


Figure 74. Placement of French Drain within Tree Root Zone

French drains should not be placed underneath driveways or other drivable surfaces as they are not structurally appropriate for heavy load-bearing. They can, however, be used to move water under sidewalks or pathways.

French drains should not be located within 10 feet of building foundations. In order to harvest roof drainage from building downspouts and maintain the minimum 10-foot distance, it is possible to use non-perforated pipe to link the downspout to the French drain. Install the non-perforated pipe run from the downspout to the edge of the French drain, where it will connect to a perforated pipe that runs the length of the drain basin. The perforated pipe should be placed so that the basin rock or cobble fill does not crush it. Be sure to install a screen at the top of the downspout to prevent debris from entering and clogging the pipes or French drain.

If there is potential for the drain to contribute to slope destabilization, it is advisable to engage a qualified professional to assist with design and placement.

Construction: As with all drainage projects, check with utility companies to verify locations of buried cables or gas lines BEFORE BEGINNING TO DIG. Also make sure that the drain will not negatively impact adjacent properties.

French drains should have a minimum 1% grade (a drop in elevation of one foot per every 100 feet of length) to ensure water movement through the structure. Grading should be plotted out before you begin digging. Trench size depends on how much water needs to be managed. For French drains that are not completely buried, dig the trench and fill with washed small-diameter rock, cobble or gravel until the surface is even with the adjacent ground level. Rounded rock, while not as stable as interlocking angular rock, is preferable as it provides greater void space. Depending on the surrounding soil type, it may be advisable to line the trench with filter fabric prior to filling it with rock to prevent soil from gradually filling the void spaces within the French drain. If the length of the French drain exceeds 20 feet, include a perforated pipe to facilitate even flow and release of the harvested water within the drain area. The trench should be a minimum of 5 or 6 inches wide and three to four times as deep as the pipe diameter. For drains containing perforated pipe, lay a 2-inch layer of coarse washed gravel in the bottom of the trench. Then place landscape fabric on the gravel, ensuring there is enough fabric to wrap up and around the pipe and additional fill gravel, creating a fabric tube. Lay the pipe in the trench on the gravel layer with the drainage holes facing down, if they are only on one side of the pipe. Shovel more washed gravel over and around the pipe to the required depth. Wrap the ends of the landscape fabric over the top of the gravel layer. Place a layer of coarse sand and topsoil over the top of the drain and then either an additional layer of filter fabric and mulch, plants or sod according to the location within your overall landscape. Plantings can be located at the end or along the sides of French drains to take advantage of the captured water.

Maintenance:
Preventing silt or sediment from entering or building up in the French drain is important to ensure good continued infiltration function over time. If the top surface of the drain is not completely buried, keep it free from debris and ensure it is draining within 24 hours to prevent mosquito issues.

Alternate French Drain Configurations:
French drains can be constructed in a branching pattern with a large one branching into smaller side French drains to make better use of a large amount of runoff, (See Figure 75). The bottom of the entire system must be sloped away from the building to direct the water toward particular locations such as planting areas.

French drains can also be installed vertically to create infiltration columns as illustrated in Figure 76. These can be particularly effective for improving water and oxygen availability around the perimeter of trees. Depending on the surrounding soil type, the columns may fill with silt over time but will still provide better infiltration and aeration to tree roots than unaltered native soil. Pre-fabricated versions of tree-root watering systems, both stand-alone and linked to irrigation, are available from some manufacturers.

Dry wells are another alternate configuration, consisting of pits filled with gravel or aggregate and used to address runoff from smaller impermeable areas.

Siting: Not appropriate for areas with high sediment loads that would clog the well. An advantage of dry wells is their potential use on steep slopes that preclude other infiltration devices.

Construction: Dry-well size should be based on the desired capacity and runoff amount from the contributing area.

Maintenance: Keep surface free of debris and check for sediment buildup, which should be removed if well function is significantly diminished.

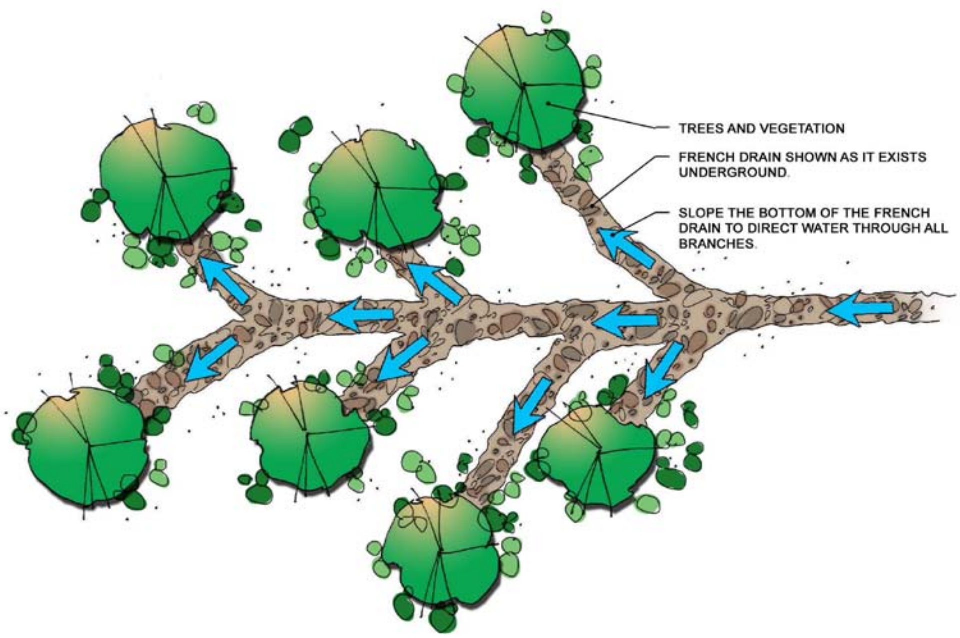


Figure 75. French Drain in Branching Series

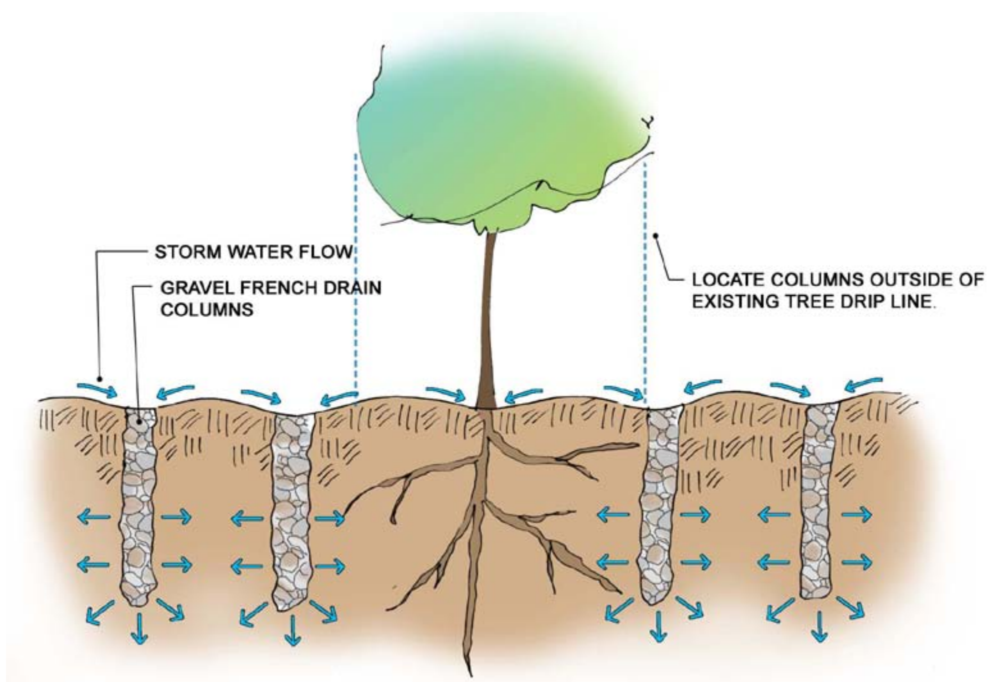


Figure 76. Vertical French Drains

Wicking Systems

Function: Wicks act like sponges, collecting stormwater runoff via a swale or other landform, storing the water, and making it available to the root systems of plants over time. Depending upon the amount of water, soil type and plant water needs, wicks can provide water for an extended period of time and act like a shallow aquifer (see Figure 77 and Figure 78). Wicks have a secondary function of erosion control as they help to reduce the amount and velocity of runoff. This secondary function can be useful when mitigating eroding slopes. Wicks can be constructed from gravel, pumice stones, straw bales or other organic material, and installed like a column or "curtain" in depressions between large plants such as shrubs or trees. When plants are placed on either side of the wick, they are given a supply of moisture at their root zones for weeks or even months after rain events. The basic idea behind wicks is to harvest runoff from the surface and direct it to a wick. The wick slowly releases the water into the soil where it can be absorbed by plant roots. Wicks can also be used in conjunction with regular and perforated piping to collect and move water from downspouts or canales away from building foundations and out into the landscape.

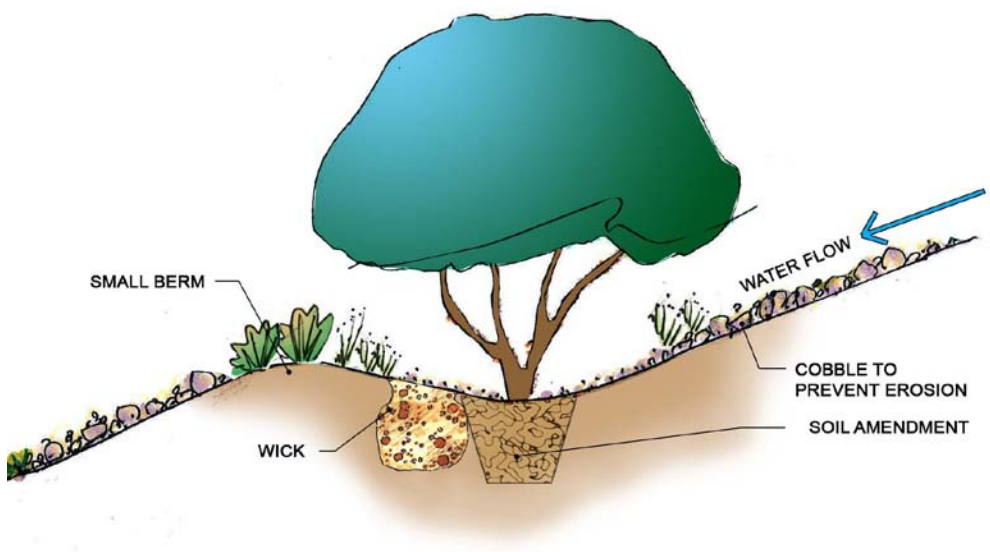


Figure 77. Wick System

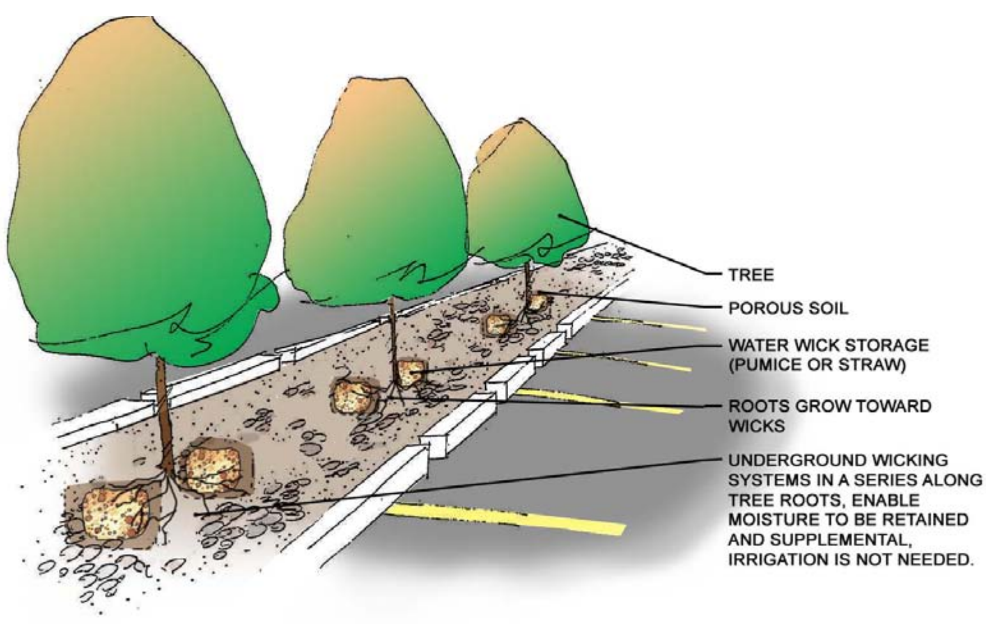


Figure 78. Wicks in Parking Island

Siting: Wicks can be positioned in a variety of locations in the landscape, preferably a minimum of 10 feet from building foundations. One option is to locate the low points near where you will be planting and simply excavate them to accommodate the wick. Another alternative is to grade the site so there is a low point, or simply dig a trench to the appropriate depth where the wick is needed. Plants can be placed along either or two sides of a wick. Locations that are cut off from adjacent stormwater flows, such as parking lot islands, are ideal locations for wicks. Wicks can also be useful for providing a supplemental water source to trees or plantings in precipitation-only landscapes, or for plantings that would benefit from an additional water source. When placing wicks near existing vegetation, care should be taken to avoid damaging plant root zones.

Construction: Dig a hole large enough (8 to 9 cubic feet) to contain a straw bale or a large amount of water-absorbing material such as pumice. Pea gravel or similarly-sized pumice stone particles work very well. Cover the wick with a layer of filter fabric or several (20 to 25) layers of newspaper, which will help to prevent dirt from clogging it, and follow with a 3-inch to 4-inch layer of cobble or other mulch.

To connect roof downspouts to wicks located at least 10 feet away from the building foundation, excavate a 3-foot diameter hole at the bottom of the downspout and then dig a trench sufficiently wide to accommodate a 4-inch pipe from the hole to the wick location. The trench should slope between 0.5 to 1% to facilitate drainage to the wick. Fill the 3-foot hole with pea gravel to a depth of 1 foot and then place a 12-inch box drain on top of the gravel. Connect the 4-inch pipe from the drain box outflow opening to the wick area. If the length of the wick itself exceeds 20 feet, include a perforated pipe to facilitate even flow and release of the harvested water within the wick. Fill the remainder of space around the drain box with gravel, and then fill and cover the wick as noted above. In case the wick becomes completely saturated, the design should also accommodate excess water by allowing any overflow to feed an adjacent water harvesting device such as a French drain or bioretention area.

Maintenance: When properly constructed, wicks require little to no maintenance. If runoff coming into the wick is high in sediment, however, the wick can become clogged over time, requiring sediment removal or wick replacement. Preventative maintenance includes checking and clearing downspout debris screens which keep material from entering and potentially blocking the pipe.

Evaporation-Loss-Reduction Devices

Mulches

Function: Some parts of Bernalillo County receive only about 8 inches of precipitation per year, while potential evaporation may exceed 100 inches annually. By covering and cooling, soil mulches can significantly reduce surface evaporation water loss, as well as weed growth and erosion. Mulches improve water and air penetration and protect shallow-rooted plants from soil temperature fluctuations and freeze damage. Over time, as they decompose, mulches also improve soil structure and nutrient availability. Mulches also are attractive. There are two basic categories of mulches: inorganic, such as gravel, cobble, decomposed granite/crusher fines or other stone material, and organic, such as pecan shells, shredded bark, pine needles, straw, leaves, grass clippings, oyster shells and the like. Inorganic mulches can also be used to help prevent erosion from slopes and berms.

Siting: Mulches can be applied over bare soils, either alone or over landscape fabric. Mulching planted areas provides the benefits noted above, and mulching water-harvesting basins, depressions and swales improves their performance. Mulch particles should be appropriately-sized to address potential loss due to wind or water flow erosion. Organic mulches tend to be lighter and are best in low-flow areas, while inorganic mulches such as cobble are more appropriate for areas that will experience higher velocity flows.

Construction: Inorganic mulches should be applied 2 to 3 inches deep and can be applied over filter fabric. Extremely fine-grained mulch can inhibit infiltration and clog soil pore spaces; so when using decomposed granite crusher fines as a mulch, it is important to wash off fine sediments first.

Organic mulches should be applied 3 to 4 inches deep directly on the soil surface. Leave several inches of space between the tree trunks or the base of plants and the mulch edge. This helps to avoid rot or mold issues.

Maintenance: Both organic and inorganic mulches deplete over time. They should be periodically replenished to maintain optimal depths for cooling soil and reducing evaporation loss. If any areas show evidence of erosion, determine and address the root cause of the issue.

Some of the soil nitrogen in contact with mulch is consumed as organic mulches decompose. This can potentially result in nitrogen deficiency, which is indicated by yellowing, primarily of lower leaves. This can be rectified by nitrogen fertilizers, applied at a rate of 2 pounds of a complete fertilizer, preferably organic, or 1/4 pound of ammonium sulfate for every 100 square feet of mulched area. Do not use "weed-and-feed" fertilizers in mulched areas.

Area and Coverage Depth of One Cubic Yard of Mulch	
Area (sq. ft.)	Depth of mulch (inches)
80	4
100	3
160	2
325	1

Advantages and Disadvantages of Mulch Types			
Mulch type	**Advantages**	**Disadvantages**	**General Comments**
Inorganic, inert mulches			
Filter fabric	Initially reduces weeds. Allows air and water penetration. Long-lasting if covered with mulch. Relatively easy to apply.	Can be costly. Degrades if exposed to sunlight or direct wear.	Preferable and better performing than black plastic. Allows water and air to infiltrate.
Decomposed granite/ crusher fines, gravel, stone, pea gravel, pebbles	Available in colors to match or complement the architecture. Relatively inexpensive.	Will not prevent growth of some weedy grasses.	Extremely fine-grained mulch can inhibit infiltration and clog soil pore spaces. Inorganic mulches can add heat load to areas lacking overstory of vegetation.
Cobble, rip-rap	Available in colors to match or complement the architecture.	Will not prevent weed growth. More labor intensive to install.	Supplementing with smaller diameter gravel or fines to fill in crevices can help prevent erosion between cobbles.
Organic Mulches			
Cocoa-bean hulls	Long-lasting, dark brown color.	Poisonous to many animals including dogs and cats. Compact; forms a crusty surface. Expensive.	Molds may form on surface. Harmless if stirred to break crust.
Crushed corncobs	Uniform in color.	May retain too much moisture at surface or compact if kept wet.	Availability limited in some areas.
Grass clippings	Readily available. Nutrient recycling.	Must be applied loosely, in thin layers to reduce matting. Herbicide residues may harm plants. Some potential to be nitrogen-robbing.	To prevent matting, allow to dry prior to application.
Leaves (composted)	Readily available. Nutrient recycling.	Not very attractive. May become matted.	
Leaves (fresh dried)	Readily available. Nutrient recycling.	Not very attractive. May blow away. Can be a fire hazard. Wet leaves compact into slimy mats.	Most appropriate in naturalized gardens or shrub masses.
Newspaper	Readily available. Good for preventing soil splashing (disease) on lower leaves or vegetables.	Don't use color inserts or red ink. Not very attractive unless covered.	Use 3 to 6 sheets thick and cover with organic mulches.
Pine needles	Do not compact.	Difficult to obtain in quantity. Can be a fire hazard.	Best for winter protection of fall-transplanted material.
Shredded bark, bark chips, chunk bark	Long-lasting, attractive. Somewhat resistant to wind erosion.	Cost relatively high. Shredded bark may compact. Large bark chunks may impede spreading perennials.	
Straw	Readily available. Inexpensive.	Blows easily. Highly flammable. Weed seeds often present.	Best used as a temporary mulch around plants needing protection in winter. Anchor with wire mesh.
Wood chips, shavings, recycled shingles	Long lasting. Readily available. Does not blow away.	Texture and color not uniform. Can cause nitrogen deficiencies in plants if incorporated into the soil.	Rustic but usually attractive. Will not compact readily.
Pecan shells	Attractive red-brown color, which weathers to a silvery grey.	Can blow away, can be scattered somewhat after installation by birds picking out remaining nut meat.	Will not compact readily.

Source: Derived from J.E. Klett, Colorado State University Extension landscape horticulturist, and professor, department of horticulture and landscape architecture. Revised from original fact sheet authored by J.R. Feucht, retired. 11/97. Revised 1/07.

Water Features and Amenities

Photo 54. Water Feature with Reduced Evaporation Water Loss

Water can be conserved through careful design and selection of ornamental water features, amenities and swimming pools. The Bernalillo County Water Conservation Ordinance limits ornamental ponds to a maximum surface area of 500 square feet; and ornamental fountains may not exceed 250 square feet of surface area. If multiple water features are used, the total combined surface area must not exceed those limits. Water must be recirculated in fountains, waterfalls and similar features. It is possible to make ornamental water features more water conservative by taking a few simple measures such as reducing evaporation loss. Photo 54 illustrates how evaporation can be minimized by covering the reservoir with attractive cobble to significantly reduce the surface area of exposed water. Locating water features where they will not be exposed to western sun in the summer and providing shade over ponds and open water fountains also reduces evaporation. Periodic inspection and appropriate maintenance to identify and eliminate leaks is also important. Using harvested rainwater to supply ornamental water features is water-conservative and has the added benefit of avoiding mineral buildup, which can reduce maintenance and cleaning requirements.

Hot Tubs and Outdoor Showers

Hot tubs, when properly maintained and covered, do not need to be emptied and refilled often; refilling frequency is dependent on usage. Water loss from hot tubs can be reduced by inspecting for and repairing leaks, and by minimizing evaporation through use of a correctly fitting cover. When emptying a hot tub, the water may be used to water the landscape if the concentration of sanitizing chemicals is low. Acids should be neutralized, chlorine levels should be 3 parts per million (ppm) or lower, and no new chemicals should be added to the hot tub for 48 to 72 hours prior to draining.

Outdoor showers should utilize low-flow showerheads and can be plumbed for graywater harvesting or the shower can be designed to allow used shower water to flow into planted areas, providing supplemental irrigation. Selection of soaps and shampoos should be appropriate for the soil conditions on the site. Any technique used to reuse shower water must comply with the New Mexico Department of Health regulations, standards, and requirements.

Swimming Pools

When appropriately managed, the water efficiency of swimming pools can be increased. Measures pool owners can take to conserve water include:

1) Keep the pool covered when not in use. Evaporation can cause the loss of up to 40 gallons per square foot of open water, which translates to 16,000 gallons for a 400-square-foot pool
2) Provide windbreaks around the pool such as fencing or landscaping. Windbreaks can help to reduce evaporation as well as heat loss.
3) Refrain from keeping the pool water level high to reduce losses from splashing and overflow.
4) Install newer water-saving pool filters; older models can use 180 to 250 gallons of water in a single back wash.
5) Clean the pool filter often to reduce the frequency at which you have to replace the pool water.

A 60-foot by 75-foot pool holds approximately 87,520 gallons of water. If it is necessary to drain a pool, the water can be utilized to water landscaping if a few simple steps are taken.

- Draining an In-ground Pool
  - Stop adding chemicals to the water. Wait 72 hours or longer if the pool is highly chlorinated. Chlorine levels 3ppm or lower are safe for most plant material.
  - Find the drain line in the filter pump; it should be located near the pump motor.
  - Attach a long hose to the drain line and take the open end out to a landscaped area.
  - Run the pump until the landscape appears unable to take in any more water, move the hose to another landscaped area. If there are no other landscaped areas to drain onto, turn off the pump.
  - Wait several hours.
  - Repeat the steps until the pool is empty.

- Draining an Above-ground Pool
  - Stop adding chemicals to the pool. Wait 72 hours or longer if pool is highly chlorinated. Chlorine levels 3ppm or lower are safe for most plant material.
  - Rent an electric pump if necessary.
  - Place the intake hose in the pool and the outlet hose in a landscaped area.
  - Plug in and turn on the pump, priming per the manufacturer's recommendations.
  - Run until the landscape appears unable to take in anymore water, then move the outlet hose to another landscaped area. If there are no other landscaped areas to drain onto, turn off the pump.
  - Wait several hours. Repeat if necessary.

Misting Systems

Water misting systems have become popular with people seeking relief from New Mexico's hot dry summers. A typical misting system uses two gallons of water per minute to cool a 1,000-square-foot space. This translates to 480 gallons over a four-hour period. Due to this large water use, misting systems are discouraged by the Standards and Guidelines. Shade trees and other landscaping provide efficient alternatives to misting systems to help cool outdoor living spaces.

Other Site Water Uses

Car Washes

New, water-recycling machinery is now available for commercial car washes. It may be possible for any nuisance flows to be captured and used in the landscape.

Permits are required for charity car washes (See Appendix C: "ABCWUA regulations charity funding" in the wastewater section).

E. Soil and Soil Amendments

Determining the type of soil present on a given site in a Bernalillo County bioregion and how it might need to be modified to improve the sites water holding capacity is also an important consideration for appropriate design for water conservation and management. The soil type will determine modifications which might be needed such as de-compaction or amendment. Soil type is also a key consideration for plant selection. The first step in determining any possible soil modifications which might be warranted is soil analysis testing, this can provide valuable information to guide decision making for these potential soil modifications and it is the most accurate means of determining a site's soil modification needs. Soil analysis can also determine whether amendment is needed and help to tailor soil amendments to the site design.

The relationship between soil and water use is based on soil structure (texture and porosity). Soil structure refers to the arrangement of solid particles of soil types and the pore spaces between them. In general, a well-structured soil will readily accept, store, and transmit water, gases and nutrients and provide a positive horticultural medium for plant growth and health. Soil texture is determined by the relative percentages of sand, silt, and clay present. Soil porosity or permeability is determined by the combination of soil structure and texture. A dense structure, such as that of clayey soils, will greatly reduce the amount of air and water that can move freely through the soil. Water moves quickly through coarser-texture soils, such as those with a high percentage of sand, and slowly through fine-texture soil with a high percentage of clay. Photo 55 shows the soil types which are the most common in Bernalillo County. A soil analysis will help determine what to do with this information. For instance, if sandy soils are predominant on a given site and the occupant would like to grow plants that require more water than the ambient landscape of sand sages and desert willow, then soil amendments of loam or humus would be important to increase the soils water holding capacity. If the occupants were in the valley and clayey soils are predominant, loosening up the soil texture with sand may be appropriate. However, the most water conservative landscape design is one that fits its soils and ecologic niche. It is always recommended for the resident or site developer to seek the assistance of green industry professionals (i.e. nursery-people, landscape architects and designers, contractors) to determine the best course of action.

Below we provide more general information about amendment and soil de-compaction.

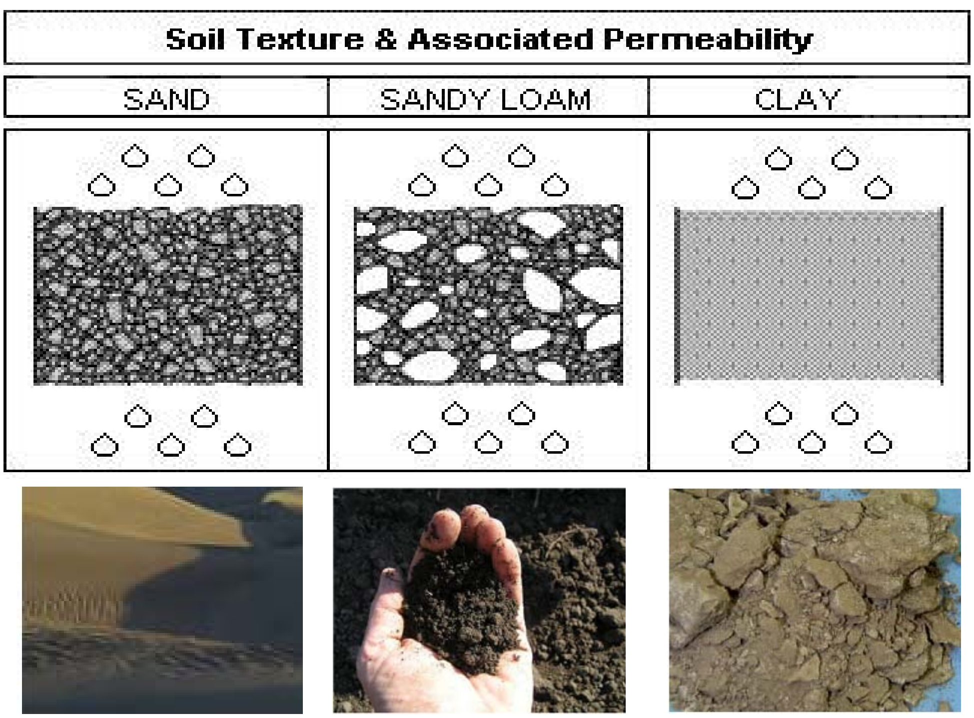


Photo 55. Soil Permeability

Soil Amendments

Soil amendments or conditioners are substances that improve the physical properties of soil and promote plant growth. Soil amendments can increase a soil's water retention qualities or increase permeability (for clayey soils). The composition of soil plays an important role in determining its water-holding capacity. Most soils in the arid Southwest lack organic matter and are limited in their water-holding capability. Organic amendments, such as composts, peat, diatomaceous earth and manure, and organic by-products from manufacturing such as coir, can improve a soil's water-retention capacity, loosen compacted soil, lower soil pH, and provide food for beneficial soil microorganisms. Inorganic materials such as gypsum, perlite, vermiculite, super-absorbent polymers, porous ceramics, and mineral-based products such as Zeolite can also be useful for improving soil texture and porosity.

The decision to use amendments should be based on the condition and type of existing soil, recommendations from soil test results, plant types that will be used, and the project budget. Choosing plants that are adapted to local soil and environmental conditions can reduce or eliminate the need for soil amendment. If amendment is required, best results are obtained by applying amendment materials in amounts based on results of soil structure and texture analysis. Generally speaking, increasing the water-holding capacity of soil is desirable. Clay soils, which already hold onto water, can benefit from amendments that increase porosity or permeability such as gypsum or sand. The benefits of improving soil to support plant and water-retention needs can offset amendment costs and can also decrease the use of fertilizers, herbicides and pesticides.

Compacted Soils and Construction Activities

Compacted soils occur when the weight of heavy machinery, vehicles, built structures or persistent foot traffic compress soil, reducing soil structure and pore space and creating a hard, solid mass. The amount and impact of compression varies depending on the soil type. Soils high in clay content, such as those in the Rio Grande Valley bioregion, compact very easily. Water infiltration into densely packed soils is greatly reduced and slowed, and much of the water can simply flow across them. The end result is that the volume and frequency of runoff from the site is increased, as is the amount of sediment and pollutants such as pesticides, fertilizers and oils carried by the runoff. The sediment and pollutants are ultimately deposited in waterways such as the Rio Grande.

Topsoil, even the small amounts in desert regions, are a valuable water conservation resource, and efforts should be made to preserve it during construction. Site preparation prior to construction should include removing and stockpiling existing topsoil. After construction, a thin layer of the stockpiled topsoil can be spread over the subsoil, which has been compacted by construction activities, and then the area can be landscaped. Because the subsoil is compacted, water does not easily infiltrate, and issues with erosion and poor plant health are common. Preventing soils from becoming compacted helps to conserve water and saves money by protecting the investment in landscape plantings, minimizing the need for dust control during construction and for post-construction reclamation efforts.

To prevent unnecessary soil compaction and destruction of existing vegetation construction activities, vehicles, equipment and materials should be kept within a prescribed area and away from the dripline of a tree. During the demolition and construction periods, existing trees and other vegetation to be retained should be surrounded with protective fencing at least out to the canopy dripline as shown in Figure 79 to prevent compaction of soils within the root zone.

Compacted soils can also occur on sites after construction due to high volumes of foot traffic. Thoughtful design and planning for pedestrian circulation keeps people on walkways and avoids soil compaction.

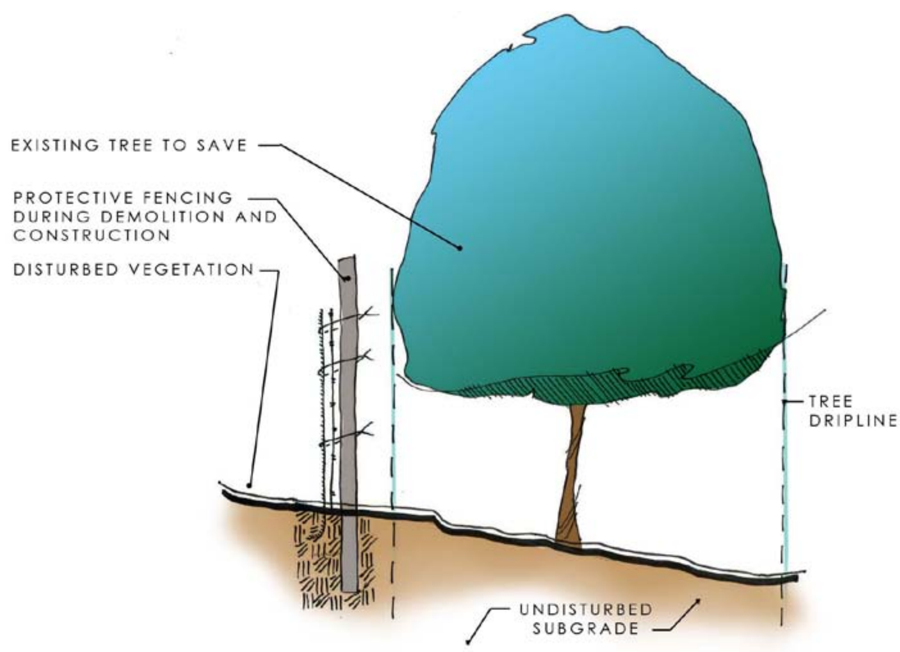


Figure 79. Tree Protection Zone

Pre-existing compacted areas can be mitigated through selective tilling or deep plowing to break up the compacted soil and enable the movement of water and air through the soil. Deep plowing should be performed prior to the application of salvaged topsoil. The addition of soil amendments can also help to restore soil infiltration capacity and fertility.

Structural Soils

Structural soils are specific mixtures of stone or sand and soil designed to provide improved growing conditions for tree rot systems under pavements or in highly compacted or confined situations. The soil mixtures support the pavement structure and allow water and air to penetrate the plant root zone while protecting it from compaction.

There are several types of structural soils in use today; one of the most well-known is called "CU-Soil," a mix patented by Cornell University's Urban Horticulture Institute (UHI). CU-soil is composed of 80% 3/4-inch to 1½-inch uniformly-sized stone aggregate with no fines, 20% clay loam soil (25% to 35% clay) and 0.03% polymer gel, which is used to hydrate and tackify the soil particles and prevent them from separating out from the aggregate matrix. The stone must be angular and consistently-sized in order to maximize the void space between the aggregate particles, allowing soil, water and air to be spread throughout the mixture, and to ensure adequate stability under pressure. In addition to sieving for consistent size, a cone separator can be used to sort out flat stones and help to further increase void space in the mix. The moisture content of the mixture should be approximately 10%. The mix is placed in 6-inch lifts or layers and can be compacted to 95% of dry density, which is the level used under most heavy-duty concrete and asphalt pavings. The UHI-recommended depth for CU-Soil is between 24 inches and 36 inches.

CU-Soil has been in existence for approximately 12 years. Some experts note concerns about whether it provides the best solution for stormwater management as only 6% to 8% of the total structural soil volume is available for water capture and retention or for long-term tree health, given the limited soil available at only 20% of the mixture volume. The CU-Soil mixture should be adapted for local conditions; increasing the clay loam content to increase the moisture-holding capacity of the mixture is advisable for Bernalillo County's desert conditions.

Another well-known structural soil mixture is commonly called "Amsterdam tree soil." It was developed in The Netherlands in the 1970s to address the decline of street trees there. The sand-based mixture is composed of medium-size coarse sand (0.22 mm), washed to remove any salts or other particles, and 4% to 5% organic matter with 2% to 4% clay. As with the aggregate in the CU-Soil mix, the sand particles should be relatively uniformly-sized. The installed depth should not exceed 40 inches and should be placed in lifts and compacted at 85% to 90%. A balance between the high compaction levels normally used for paving substrates and slightly lower levels that facilitate permeability has to be achieved. It is interesting to note that in Europe 85% to 90% levels are commonly used for streetscape paving schemes.

Some experts state that sand mixes are superior to aggregate-based mixes in terms of stormwater management, cost-effectiveness and promoting tree health and growth.

Structural soil mixtures based on ESCS aggregate present another option. Called air-entrained soils by Henry Arnold, the landscape architect who originally developed them, ESCS is a ceramic material. It is produced by firing shale, clay and slate until they expand and vitrify, creating a lightweight material with internal pore structures that allow it to absorb and then release water and air. Generally the mixture consists of 50% to 65% ESCS aggregate with 5% to 10% organic matter and topsoil and 15% clay. Various versions of this type of soil mixture have been used over the last 20 years with positive results. An advantage of this type of structural soil is its ability to support heavy and continuous pedestrian traffic. Another is its high proportion of soil and organic matter relative to the amount of aggregate, which translates to greater stormwater management capacity and increased growth medium for trees.

In addition to structural soils, alternatives such as proprietary engineered cells, modular units that resemble plastic milk crates, can be used to create tree-root-friendly zones under paved surfaces such as sidewalks, plazas or parking spaces (Photo 56). The systems are highly flexible, can withstand significant traffic loads, and an increasing variety is available on the market. One advantage of engineered cells over structural soils is the increased volume of un-compacted soil provided which allows for increased stormwater management and room for root growth. The impact of the cells can be further increased by incorporating engineered bioretention soil mixtures that filter out the nitrogen, heavy metals, and other pollutants common in urban watersheds while providing optimal conditions for trees. Bioretention soil mixtures are typically 65% sand, 20% compost and 15% clay silt.

Urban Trees and Soils

Healthy urban trees provide significant stormwater management benefits and also reduce the heat island effect and pollution levels. Large trees have the greatest beneficial impact. The key limiters to urban tree growth are highly compacted, poor quality soils and small planting spaces. In streetscapes and ultra-urban sites, adequate amounts of un-compacted soil are critical to long-term tree growth and health. A general rule of thumb is to provide two cubic feet of soil volume for each square foot of mature tree canopy size. For native trees an equivalent amount of un-compacted native soil is appropriate. For example, a 500-square-foot canopy tree should be provided with 1,000 cubic feet of good quality, un-compacted soil.

Photo 56. Modular Engineered Silva Cell

F. Water-Conserving Irrigation

Introduction

A well-designed and maintained irrigation systems is essential to achieving a beautiful, healthy and water-conservative site and landscape. This section of the guidelines provides basic descriptions of the different types of irrigation systems, issues to consider when determining how to irrigate, and recommended best practices for designing and maintaining an irrigation system. Additional information is available through the resources listed at the end of this section.

It has been estimated that up to 60% of municipal water consumption is used for landscape irrigation and that more than 1.5 billion gallons of water a day is lost nationwide due to irrigation system inefficiencies. By some estimates more than 50% of the water used for landscape irrigation purposes is wasted due to evaporation or runoff caused by overwatering. A water-conserving irrigation system applies water by the most efficient method possible and only when and where it is needed. A good rule of thumb is to water deeply but less frequently in order to encourage deeper root growth. This in turn enables plants to draw moisture from a larger area of soil, increasing their ability to tolerate drought. It is important to account for the soil type of the site when planning irrigation watering durations and frequencies. As an example, water travels more quickly through sandy soils, so more frequent watering will be needed than for a site with higher clay soils, which drain more slowly.

As noted in the section, "Recommended Steps for Water-Conserving Landscape Design," an irrigation system based on hydrozones is fundamental to reducing landscape water use. A hydrozone-based landscape design groups together plants with similar water requirements. The irrigation system can then be designed to align the most appropriate and efficient type of irrigation to each hydrozone and allows each zone to be watered separately. For example, lower-water-use plant groups may be drip-irrigated, whereas higher-water-use turf areas may use sprinklers.

There are basically two major approaches to irrigation, passive and active. Passive irrigation systems are "low technology" solutions that use gravity to deliver water to targeted areas in the landscape via channels, hoses or other conveyance devices. Active irrigation systems are mechanized and move water under pressure through the delivery network of pipes or hoses and out to the targeted landscape areas. Additional information on passive irrigation and water harvesting devices is available in the "Water-Conserving Landscape Devices And Best Management Practices" section of this chapter.

Irrigation System Components

The basic components of most irrigation systems are:

Controller – The clock or brain of the irrigation system, determining when and for how long each irrigation zone (with an automatic valve) will be watered. Photo 57 shows a typical controller. Care should be taken in programming basic controllers to ensure watering schedules are based on the irrigation needs of each hydrozone, as well as on soil and slope conditions.

Smart controllers enable irrigation to occur when it is actually needed rather than on a preset schedule. They utilize data from sensors and weather stations to determine when and how much irrigation is needed, offering the greatest potential for water-efficient irrigation. A range of sensor and weather station data types can be included such as rain, wind, evapotranspiration, flow and soil moisture. Researching current product offerings is essential as irrigation technology is constantly evolving, providing an ever-increasing range of cost-effective options for improving the irrigation system water efficiency.

Photo 57. Irrigation Controller

There are many additional controller features that can help promote water-conserving irrigation including:

- Cycle-and-soak or interval programming options, which help reduce runoff by accommodating site conditions such as hard, compacted or clay soils or slopes that require watering in increments to allow the soil adequate time for absorption, enabling deeper penetration of subsequent irrigation.
- Percentage increase/decrease or water budgeting features, which allow quick uniform adjustment of watering periods for all zones on a system. These are useful when adjusting irrigation schedules up or down to accommodate seasonal or monthly changes in plant water needs.
- Rain-delay features, which adjust irrigation schedules to avoid watering during or immediately after rain.
- Soil moisture sensors measure the amount of water in the soil and let the controller know when it is dry enough and the plants need water.
- Weather-based controls (Smart Controllers) rely on data gathered from nearby weather stations. This information is relayed to the controller via a pager signal and automatically adjusts the programmed watering schedule.
- Multiple programming allows the flexibility to water plants of varying microclimates or water needs.
- Non-volatile memory retains the programs in the controller's memory in the event of a power outage.

Backflow preventer – Required by ordinance and keeps irrigation water from being siphoned back into the potable water supply and potentially contaminating it. There are several types of backflow preventers: reduced pressure, pressure vacuum breaker, anti-siphon valve and double-check type. Be sure to verify local requirements when selecting a backflow prevention device.

Pressure regulator – Used to reduce system water pressure. They are often needed to deliver the lower pressure required for optimal operation of a drip system.

Automatic control valves – Activated by a signal from the controller, they control the flow of water into the designated irrigation zone. The concept of hydrozoning is the foundation to a water-efficient irrigation system design. An irrigation system based on hydrozones can significantly reduce landscape water use by providing separate valves for irrigation zones that match the water requirements of the various plant groups and allow them to be watered separately. Also, lower-water-use plant groups may be drip-irrigated, whereas higher-water-use turf areas may use sprinklers. It is necessary to select the proper type of irrigation for each hydrozone.

Photo 58. Pressure Regulator

Irrigation System Types

An irrigation system comprises a set of components that generally includes a water source (meter or well), a water distribution network and water delivery devices. Irrigation systems can typically be classified into five types: Drip and low-flow, bubbler, spray, flood and hand watering. Flood irrigation will not be discussed in detail as it is subject to regulations by irrigation organizations such as the Middle Rio Grande Conservancy District and Acequia Associations; however, it should be noted that this irrigation method loses significant amounts of water to evaporation.

Drip and Low-Flow Systems

Drip irrigation systems are highly efficient for providing water to plants in the landscape and are ideal for xeric landscapes. A properly designed system using low-flow drip irrigation can achieve efficiency levels of more than 90% and virtually eliminate water waste. Drip systems provide a slow, steady amount of water directly to the root zone of the plant, minimizing loss due to evaporation and application in areas that are not planted. They also reduce loss due from runoff and overspray.

Drip irrigation systems are typically operated at a lower water pressure than sprinklers, and pressure regulation is needed to maintain this lower pressure. The water pressure needed for drip systems is typically in the range of 10 to 20 psi. A wide variety of products are available for drip irrigating, including individual emitters, multi-outlet emitter devices, dripline and microsprays. The components of drip systems are described below (see also Figure 80).

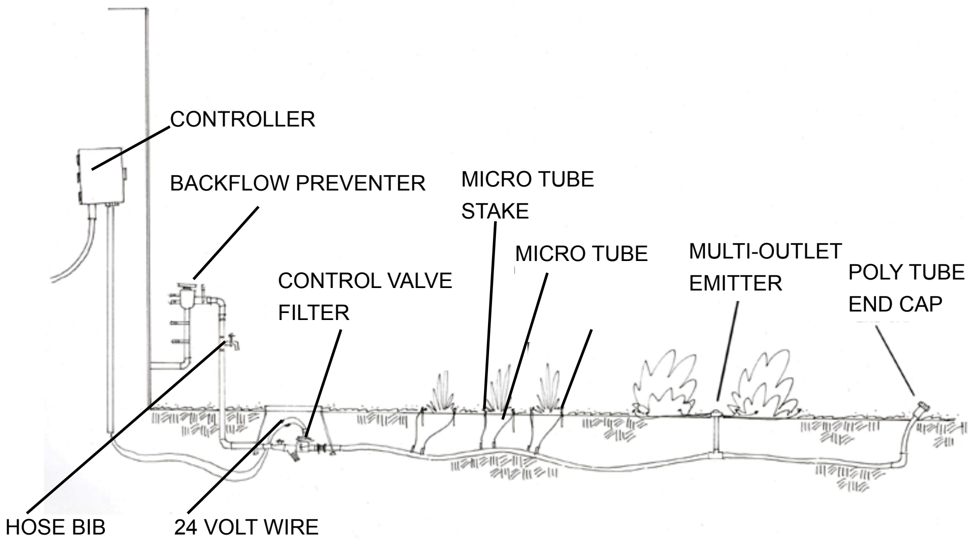


Figure 80. Drip Irrigation System Components

- **Filter** – Often are included in drip systems upstream from all control valves to prevent particulate matter in the water such as sand or silt from building up and clogging any part of the system. Some filters can be removed and washed while others are self-cleaning.

- **Micro-tubing** – Is flexible polyethylene distribution tubing that connects to individual drip emitters. It is generally available in 1/4-inch or 1/2-inch diameter sizes, relatively inexpensive, easy to install and repair, and is resistant to Ultra-violet light damage.

- **Drip emitters** – Are small watering devices that deliver water at very low pressure and rates measured in gallons per hour (gph). They are available in a variety of types and forms, including self-cleaning, pressure-compensating, and micro-spray emitters. Output from "non-compensating" emitters increases or decreases as tube line pressure increases or decreases. Emitters categorized as "pressure-compensating" are designed to deliver the same amount of water over a fairly wide range of tubing line pressures. Depending on the design of the drip irrigation system, this can be an important consideration.

Photo 59. Drip Emitter

The number of emitters should be based on the plant type and size, soil type, and be sufficient to deliver the maximum daily water requirement for the mature plant size. Emitter flow rates should be proportional to the plant type and size.

Higher-water-use plants may need more emitters than native or drought-tolerant plants of the same size.

Suggested Drip Emitter Quantities			
Plant Type	**Mature Canopy Size in Feet**	**Number of Emitters**	**Emitter Flow Rate (gallons per hour)**
Groundcover/Small Shrub/Ornamental Grass	1-3	1	.5 - 1
Large Shrubs	4-6	2	2
Small Trees	7-10	3	2
Trees	11-14 15-20 21+	4-6 6-12 12+	2-4 2-4 4

Emitters should be placed uphill from the plant. For plants located on steep slopes, create mini-basins or a depression around the base of the plant to receive water from the emitters while preventing erosion and runoff.

For new plantings, install emitters halfway between the base of the plant and the outer edge of the rootball. This is termed the dripline. As plants grow and mature, emitters should be moved to water the root zone (the soil area that surrounds the plant's roots) (see Figure 81).

Most roots spread 1.5 to 4 times the plant's canopy and penetrate 2 to 3 feet deep. For existing or mature plants, place emitters to deliver water at the edge of the mature root zone, (see Figure 82).

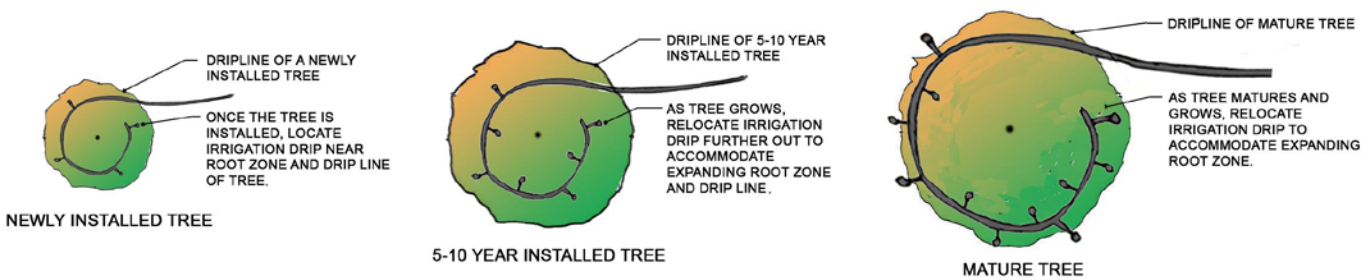


Figure 81. Adjusted Emitter Placement Over Time

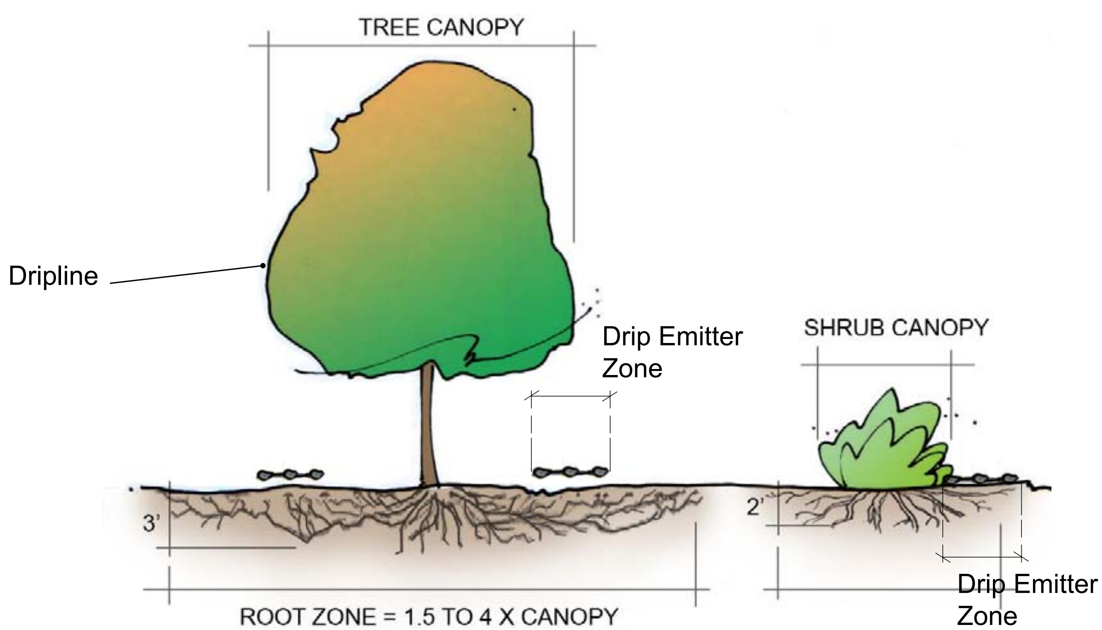


Figure 82. Approximate Sizes of Mature Root Zones

- **Dripline -** Is plastic tubing that has been pre-drilled with regularly spaced holes or in-line emitters that deliver water at a consistent rate and can be used for watering containers or narrow planting areas. Another type of dripline is made of porous tubing similar to soaker hose that allows water to seep through the entire tube wall.

Photo 60. In-line Emitter

Photo 61. Soaker Hose

- **Multi-outlet emitters** (also known as multi-emitter hydrants) - Deliver water from one central riser pipe to multiple independent outlets. Each outlet's flow rate can be connected to micro-tubing with drip emitters to deliver different amounts of water to the landscape. Multi-outlet emitters with pressure-reducing components can be used to replace existing sprinkler heads when converting turf areas to xeriscape.

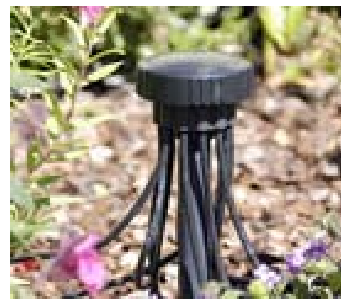


Photo 62. Multi-outlet Emitter

Bubblers

Bubblers are most effective when deep watering is desired, such as for trees or shrubs. They are simple to install and provide water in an "umbrella" pattern over a small area, usually at higher gallon-per-hour rates than drip emitters. They can be installed on pop-up heads or fixed risers. Pop-up heads are an additional expense; however, they are preferable when the bubblers will be located in areas subject to foot traffic, as they can prevent damage to the bubblers.

Photo 63. Bubbler

Bubblers are also available as part of pre-fabricated Root Watering Systems that apply irrigation water to trees or shrubs directly in the root zone. These systems also increase oxygen supply to the root zone and can be especially beneficial in situations involving compacted soils. An illustration of this system is show in Figure 83.

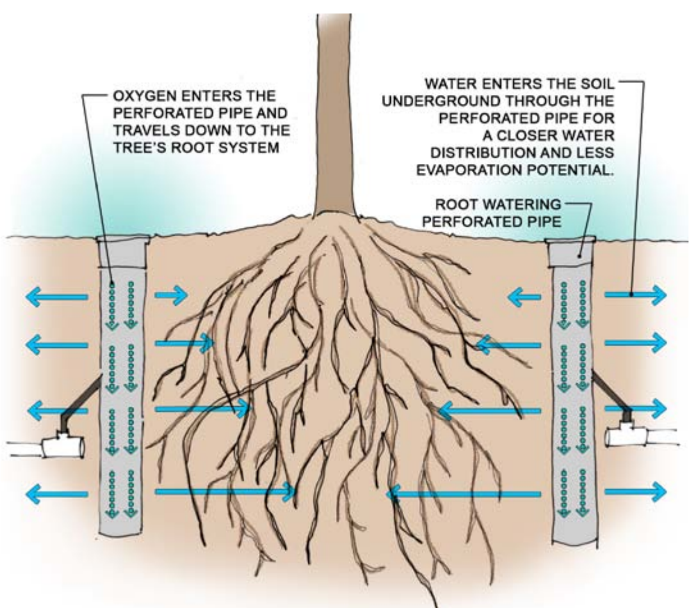


Figure 83. Root-Watering System

Stream bubblers can be used when irrigating densely planted shrub or ground cover areas. They provide a consistent stream of water with a variety of choices for the radius of throw (Photo 64).

Photo 64. Stream Bubbler

Spray Systems

Spray systems are most commonly used for turf grass or large areas of other groundcovers and are generally viewed as the most efficient irrigation method for lawns. Spray systems apply water in gallons per minute and lose significant amounts of water due to evaporation. They must be carefully designed, installed and maintained to avoid additional loss due to overspray (application of water to adjacent areas that do not require irrigation such as sidewalks, walls or driveways). Pressure regulation is particularly important to avoid producing overspray or mists that waste water. Another key design and maintenance objective for water-efficient spray irrigation is uniform application of water. Poor uniformity of irrigation application can result in some areas being drier than others. Often the irrigation being supplied by the entire system is increased in an effort to address the dry areas, which results in some areas being over-watered and water being wasted. Verifying and adjusting heads to ensure that they are positioned and operating correctly is an important maintenance task. The efficiency of older systems can be improved by replacing old sprinkler heads with newer, more efficient models.

There are several types of sprinklers available:

- **Pop-up sprinklers -** Are activated by water pressure when the control valve is opened and retract when the valve is shut off. This is useful in situations where the sprinklers may be walked on, or where there is potential for vandalism. They are available in a variety of pop-up heights, heads and nozzle-types that allow the irrigation system to be tailored to the site. Sprinklers emit a fixed spray in a 5- to 15-foot radius and so are generally appropriate for smaller areas.

- **Fixed-spray heads -** Deliver a fan of small water droplets and are appropriate for watering smaller areas.

Photo 65. Pop Up Sprinklers

- **Nozzles -** Are an interchangeable part of a sprinkler head and create a full, half-circle or quarter-circle spray pattern. They determine the radius of throw and the rate of water application for the head.

Photo 66. Full Radius

Photo 67. Half Radius

Photo 68. Quarter Radius

- **Matched-precipitation-rate sprinklers -** Also called rotary nozzles, these provide more uniform coverage by allowing a variety of spray arcs and radii to be used on the same irrigation zone while still achieving consistent spray distance and application rates. They can be installed onto pop-up spray heads and are more water efficient than conventional spray heads as they apply water at lower speeds and lower precipitation rates, allowing the soil to absorb more of the water received.

- **Rotors -** Can be gear-driven or impact types. Rotors are appropriate for larger watering areas such as playing fields or parks, with coverage ranging up to a 45-foot radius. Rotors rotate slowly as they distribute single or multiple streams of water. Rotors are less likely to cause runoff, as they apply water at a slower rate than spray heads. Like spray heads, rotors are available on fixed or pop-up risers.

  - **Impact rotors** project a single rotating stream of water in a circular or part-circular pattern.

  - **Stream rotors** have multiple rotating streams of water and are appropriate for watering medium-sized areas.

  - **Micro-rotors** and **low pressure rotary heads** are now available and provide a more efficient alternative to the spray head for smaller areas.

Photo 69. Gear Driven Rotor

Photo 70. Rain Sensor

Photo 71. Soil Moisture Sensor

- **Rain shutoff devices or rain sensors -** Prevent the irrigation system from running if it has rained recently. These relatively inexpensive devices generally allow the user to specify the amount of precipitation that will trigger the shutoff. Irrigation resumes when the sensor has dried out and returned to the baseline condition.

- **Soil moisture sensors -** Measure the level of moisture in the soil and trigger the irrigation system to run when the conditions are sufficiently dry, preventing it from operating when the soil is saturated. Many soil sensors allow the user to program the moisture level that triggers the system.

- **Hand watering -** The efficiency is highly dependent on the person doing the watering and can easily result in over- or under-watering. When hand-watering, care should be taken to apply water deeply but less frequently to encourage deeper root growth and create a healthy root zone. The depth to which water is penetrating can be verified by pushing a 1/4-inch or 3/8-inch metal rod into the ground after watering. The rod will stop when it hits dry soil, indicating the water penetration depth. Ideally the water should percolate down only to the bottom or slightly below the bottom of the plant root zone, as water beyond this level is not usable by the plant. Attaching a sprayhead or nozzle with a shut off valve at the dispensing end can increase the efficiency of hand watering by allowing the user to cut off water quickly whenever necessary. Installing a faucet timer that automatically shuts off the water, or using a timer as a reminder can help to avoid over-watering.

WATER-CONSERVING STRATEGIES FOR SPRINKLERS

- Sprinklers are designed to irrigate with "head to head" coverage. Improperly spaced sprinklers will have poor uniformity in their coverage, leading to over- or under-watering.
- Use sprinkler heads with built-in pressure regulators that allow the system to operate at lower pressures, saving water that can be lost due to misting. For every 5 psi that the system pressure is lowered, water use is lowered from six to eight percent.
- Nozzles control the amount of water flowing from a sprinkler and the distance the water will travel. High-efficiency nozzles save water by creating larger water droplets, which in turn produce a more uniform spray pattern.

Irrigation Water Supply Options

The supply options listed below should be considered, as they can reduce or eliminate reliance on municipal, county or other potable water sources. The use of natural precipitation should be also maximized through thoughtful site design for water harvesting to supplement artificial irrigation systems and lessen demand on other water supply sources.

Recycled and Reclaimed Water

- ***Graywater*** - Non-potable water is an excellent alternative irrigation supply and offers the opportunity to reduce use of potable water.

  The New Mexico Environment Department (NMED) defines graywater as "untreated household wastewater that has not come in contact with toilet waste and includes wastewater from bathtubs, showers, washbasins, clothes washing machines and laundry tubs, but does not include wastewater from kitchen sinks or dishwashers or laundry water from the washing of material soiled with human excreta, such as diapers." NMED notes that, "Graywater is distinguished from 'black water,' which is wastewater from toilets, kitchen sinks and dishwashers."

  A permit is not required to use graywater for **residential** irrigation if the daily amount of graywater discharged does not exceed 250 gallons. Other uses may require permits and be subject to particular requirements; for detailed information on current graywater use requirements and restrictions see the New Mexico Environment Department website at http://www.nmenv.state.nm.us and search on the term "graywater."

  In a typical graywater system, water that would normally be discharged for sewage treatment is collected, treated to remove suspended solids and contaminants and then reused. At a minimum graywater systems include the following components:
  - storage tank(s)
  - filter(s)
  - pump
  - valves
  - purple PVC piping (purple designates the water being piped as non-potable)
  - irrigation heads with protected openings or purple non-potable marker)

  It is important to use valves and filters designed for gray or reclaimed water supply as they are designed to address potential issues such as clogging and wear caused by impurities in non-potable water.

  Graywater systems must be installed in accordance with local plumbing codes. Appropriate design, installation and maintenance of a graywater system are critical to ensuring a safe and reliable supply of graywater.

  #### *Graywater Use*
  - Graywater should not be used for irrigation if there is not more than five vertical feet between your landscape and the water table below.
  - Graywater should never be discharged into a lake, stream or arroyo.
  - Graywater must be discharged using a hose, drip system or bubblers and should never be sprayed.
  - Any piping used for discharge of graywater should be marked as non-potable.
  - Be sure that the water used cannot run off your site.
  - Take measures to reduce contact with humans or pets.
  - Graywater should not be permitted to pond.
  - Overflow from the graywater distribution system should be directed into the sanitary sewer.

The amount of graywater available for irrigation is a function of the amount of wastewater produced by the users of the site's facilities. Water-conserving fixtures and appliances will impact the amount of wastewater produced. When designing graywater irrigation systems it is important to calculate the amount of wastewater available and to match that to the landscape irrigation needs. If graywater supply is not sufficient to meet total demand, supplemental water sources may be needed. It may be necessary to divert some or all graywater to the sewer or septic system if year-round demand does not match supply. Outdoor irrigation needs are largely seasonal, but including evergreen plant materials can help boost non-growing season demand.

Graywater contributes nutrients that are beneficial to plant and soil health. Gray or reclaimed water can also be more conducive to plant health than treated potable water that contains chlorine and other chemicals that can adversely impact plant health. Graywater is generally alkaline and typically contains more salts than potable water. Native plants adapted to local conditions are less likely to be impacted by the additional alkalinity and salts, but plants that are not alkaline and salt-tolerant may be impacted. Combining reclaimed water with potable water, or rotating irrigation with fresh water can help remedy this issue, and are recommended if monitoring shows evidence of salt buildup.

- ***Other recycled and reclaimed water sources*** - Condensate from central air systems is another potential source of supplemental irrigation water supply. Condensate is essentially equivalent to distilled water as it is mineral-free and has a total dissolved solids (TDS) level near zero. It should be noted that the lack of minerals in the water makes it corrosive to metals such as steel and iron and can also inhibit plants' nutrient uptake ability. The latter issue can be addressed by using a fertilizer injection system to add nutrients to the condensate before applying it to the planting areas. Because it might contain heavy metals from contact with cooling coils and other HVAC equipment, condensate should not be used for human consumption. Depending on the amount of condensate available, combining rainwater harvesting and recovered condensate for irrigation can deliver more consistent amounts of harvested water. Mixing supply in this manner can also help to dilute heavy metal content.

  Another potential source of reclaimed water is the Albuquerque Bernalillo County Water Utility Authority. For more information contact the ABCWUA http://www.abcwua.org.

Storage Systems

Storing harvested rainwater underground or aboveground is a viable option for many sites. Most ground-storage methods are simple enough to be installed by a landscape contractor, although the calculations for sizing them may require professional services. Regulations for ground-storage systems exist for particular areas within each of the biozones identified in this document due to flood plain designation, as in the Rio Grande Valley, or other factors. Contact Bernalillo County Public Works for applicable requirements for your site.

- ***Rain barrels*** - Are tanks that hold roof runoff until it can be used either for hand watering or by an irrigation system. It is important to compare the capacity of the tank with the potential volumes of water coming off the roof. Rain barrels typically range in size from 20 to 150 gallons and can be purchased in a variety of materials such as heavy plastic or wood. They can also be linked together to increase capacity. The barrel should also have an overflow mechanism to handle excess water. Most rain barrels include a spigot or hose attachment near the bottom so the collected water can be drained for use. Both the overflow mechanism and hose attachment should be oriented so they drain excess water away from the building to avoid potential foundation damage. A screen cover is required to keep out debris and prevent mosquito breeding. The barrel cover should also be designed to prevent animals or children from climbing into the barrel. Rain barrels should be placed on a secure, level base as they can weigh over 500 pounds when full. Photo 72 shows a typical rain barrel.

Photo 72. Rain Barrel

  Maintenance: Check that lids and hoses are attached and properly placed, that the spigot or other hardware is functioning properly, and that water is being dispersed in expected locations. Check and clear screens and downspouts feeding barrels.

- ***Cisterns*** **-** Cisterns are water storage tanks and can be used to store harvested stormwater above or below ground, as shown in Photo 73 and Photo 74. Relatively common in some parts of the US in the first half of the 20th century, the popularity of cisterns is increasing once again as water conservation is being encouraged. Present-day cisterns are predominantly used for irrigation due to concerns over water quality however; modern cisterns can be outfitted with filters or other water purification methods when the water is meant for human or animal consumption.

Photo 73. Above-ground Cistern

Photo 74. Below-ground Cistern

Cisterns come in a wide range of sizes, materials and shapes, and can be constructed individually or in a connected series where the overflow from one cistern flows into the next. A number of manufacturers offer modular cistern systems which provide highly flexible configuration and capacity options. Some manufacturers also offer turn-key cistern design and installation services.

The appropriate tank volume is based on average rainfall amounts and the total square footage of area that will collect stormwater. Groups of residential units, such as apartments and commercial and office buildings, offer significant opportunities for collecting rainwater using cisterns. Cost and space required for the tank are additional considerations.

A cistern should be placed on a level surface or pad. Potential damage to adjacent features should be taken into account when determining where to locate the tank. Cisterns should be located for ease of maintenance or replacement. The locations of downspouts feeding into the cistern are also a factor. If the water stored in the tank will be accessed via a gravity-feed system, the height of the tank location relative to the landscape areas that will use the stored water is also a consideration.

Roof Water Harvesting Capacity

Roof Area (sqft)	Total Water Harvested (cuft)	(gal)
1000	633	4737
2000	1267	9475
3000	1900	14212
4000	2533	18949
5000	3167	23687
6000	3800	28424
7000	4433	33161
8000	5067	37899
9000	5700	42636
10000	6333	47373
11000	6967	52111
12000	7600	56848
13000	8233	61585
14000	8867	66323
15000	9500	71060
16000	10133	75797
17000	10767	80535
18000	11400	85272
19000	12033	90009
20000	12667	94747
25000	15833	118433
30000	19000	142120
35000	22167	165807
40000	25333	189493
45000	28500	213180
50000	31667	236867

Note: Harvesting calculations based upon a 9.5 in/yr annual rainfall and an 80% collection efficiency

Water from the cistern can also be discharged using a pump connected to an irrigation system, hose, perforated pipe or surface channel that conveys water to the landscape (see Figure 84).

Cisterns have a removable lid or entry port for maintenance access. Cisterns can be left open to catch rain or connected to more elaborate systems that collect water from several locations and direct it into the cistern. Open systems should be designed to minimize water loss due to evaporation and to prevent algae growth. Outlet pipes should be positioned a few inches above the bottom of the tank to avoid sucking out sediment settled on the tank bottom. The tank should have an overflow pipe that does not require a pump to function with a capacity equal or greater than the inlet pipe. All inlets and outlets should be screened to keep mosquitoes, animals and debris out of the tank. In addition, cistern water should be filtered prior to entering the irrigation system to avoid potential clogging.

Maintenance: The tank, screens on inlet and outlet pipes, and any gutters feeding into the cistern should be cleaned periodically to remove accumulated debris. The interior of the tank should also be checked periodically and maintained in accordance with manufacturer's requirements or according to best practices for the tank material. Performance of the overflow pipe should also be verified following significant storm events.

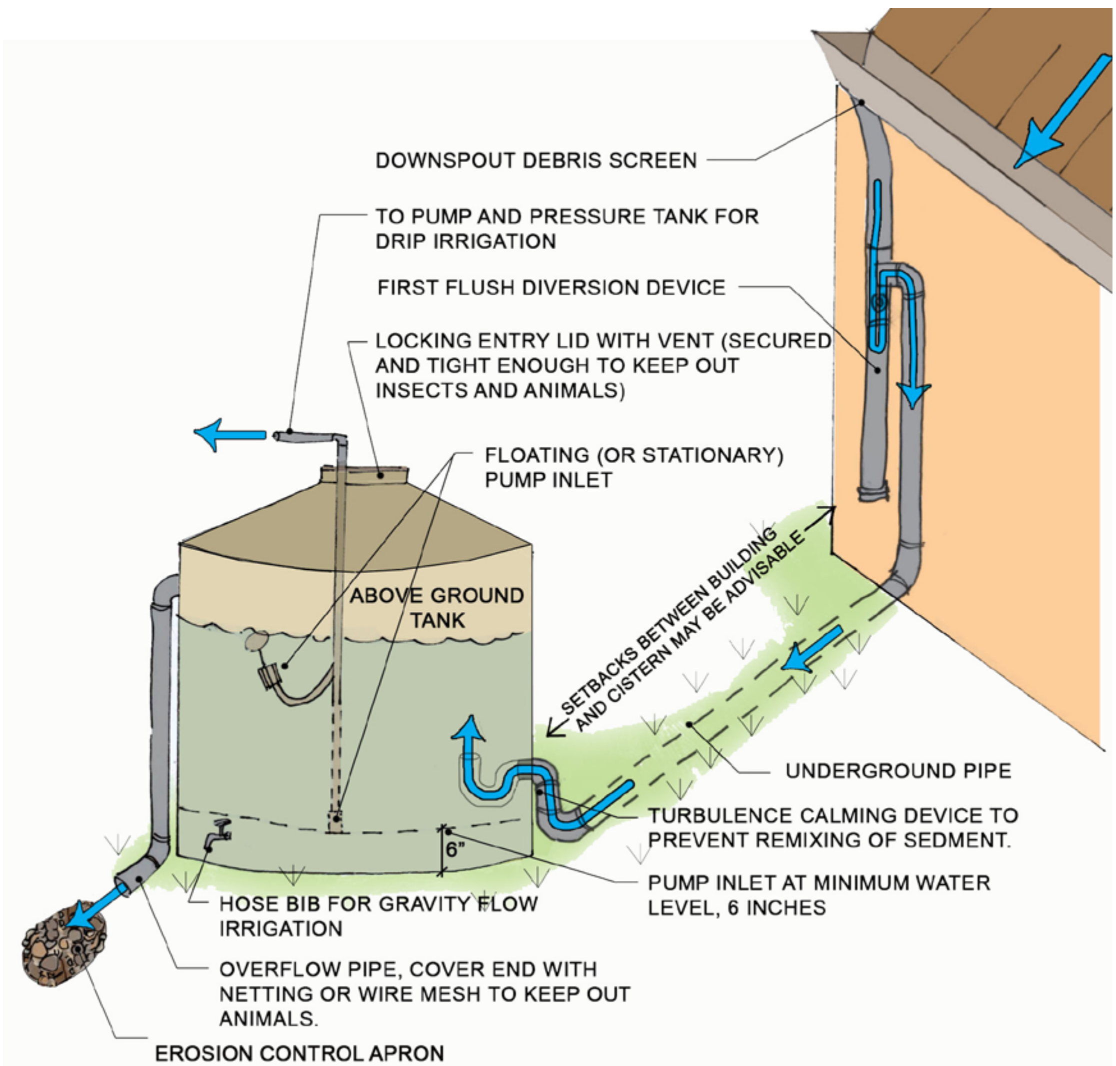


Figure 84. Cistern System

Irrigation System Design, Installation and Management

Designing an irrigation system requires an understanding of how the many aspects of the landscape work together. These aspects include site grading, microclimates, soil types and infiltration rates, and the water requirements of different plants. It also involves a basic understanding of hydraulics in order to calculate pipe sizes and system pressure losses. In order to develop an effective watering schedule, a basic working knowledge of plant types and evapotranspiration rates is needed. In addition, local plumbing codes and ordinances must be followed. Licensed irrigation designers and contractors, and some irrigation supply companies, offer irrigation system design and installation services. For information regarding considerations when selecting a professional see the "Hiring a Professional" section that follows.

Hiring a Professional

Certified irrigation designers are trained to evaluate specific site conditions and develop irrigation plans tailored to irrigate the site for optimum water efficiency and plant health. They also are able to provide installation oversight to ensure the project is built according to their specifications. They should also be well-versed in the latest irrigation technology available. As-built or record drawings should be provided to document any variations in the installation of the system design. The end user should also be provided with all product warranties and operating instructions.

If your site will have a landscape maintenance manager, you may wish to consider hiring a Landscape Irrigation Auditor certified by the Irrigation Association. Certified Landscape Irrigation Auditors are trained in exterior water management and can help to ensure that water efficiency is maximized in your landscape.

- ***Qualifications -*** When searching for a professional irrigation designer or contractor to design or install an irrigation system, there are certain qualifications you should consider.

  The tips below can be used to help you make an informed choice for your irrigation project.

  - **Certification and Licensing -** New Mexico state law requires anyone who contracts to do work to be licensed according to the Construction Industries Licensing Act. Licensed contractors are regulated by laws designed to protect the public, and hiring a licensed contractor is highly advisable. When hiring a contractor ask for their state license number and call the State License Board to verify that it is issued for the appropriate discipline, is current, and is in good standing.

    The Irrigation Association Certification Board manages industry certifications for irrigation designers and contractors. These require that the contractor achieve certain levels of irrigation experience and education, pass a series of examinations, agree to abide by the Association's code of ethics, and receive ongoing education yearly. The designations include Certified Irrigation Designer (CID), Certified Irrigation Contractor (CIC), Certified Landscape Water Manager (CLWM) and Certified Landscape Irrigation Auditor (CLIA).

  - **References -** Ask for and check references and request a list of similar jobs the contractor has recently completed in your area. If possible, look at the work and talk to the owners about their experience with the contractor.

  - **Water Management -** Ensure your contractor will design your system with water efficiency in mind and use appropriate irrigation methods such as drip irrigation to achieve that efficiency.

  - **Written proposals -** A professional contractor should provide a written proposal that includes a detailed list of every task to be performed, along with the dollar amount.

  - **Insurance -** Reputable professionals will carry appropriate insurance policies to protect you and your property. Ask if the contractor has liability and workers' compensation insurance and request certificates in writing.

  - **Contract -** For your protection, insist on a written contract, regardless of the amount. After the contract is signed, any changes you and the contractor agree to make in the work or the materials to be used must be in writing. This written "change order" must also include any additions or reductions in the total job price. Here is a list of basic elements you will find in most irrigation contracts.

- Specific costs of materials to be installed
- Specified start date and an estimated completion date
- Statement regarding payment arrangements such as down payment, progress payment and balance due
- The name, street address and telephone number of the contractor
- Complete description of the work to be done and materials to be used (including quantities, sizes, models and brands of irrigation equipment)
- Warranties covering materials and workmanship
- Statement that the contractor will do any necessary cleanup and removal of debris after the job is completed
- "Notice to Owner" explaining the state's mechanic's lien laws and the ways to protect yourself and your property
- "Notice of Cancellation" informing you how long you have after signing the contract to cancel
- Statement requiring the contractor to provide proper lien releases for suppliers
- Statement of contractor's obligation to obtain all permits
- Validation of any required license and certificates of insurance, not just copies
- Statement that the work will meet the standards specified in the contract
- Statement that contractor will be responsible for all clean up.

- **Customer Service -** The contractor you hire should be available if you have questions or if a problem arises in the future. In addition, ask questions about how to reset the controller once your new turf is established.

- **Key Inspection Points and Testing -** The contractor's work should be inspected when the locations of all the piping have been laid out on the project site. A pressure test should be performed to verify that all piping has been installed properly and that there are no leaks in the system.

- **Final Walk-through -** A final walkthrough should be conducted to inspect and verify that all work is complete and satisfactory. During the walk-through, the contractor should demonstrate all of the capabilities of the irrigation controller and that the controller has been properly programmed for all irrigation zones. The locations of all sprinklers, bubblers, drip emitters, etc., should follow the original plans. All heads should be installed at the proper height. Any deviations from the original plans should be documented for future reference.

Reducing Water Use

When initially installed, most plant materials will require more frequent deep watering in order to establish a healthy root zone. Once established, plants should be irrigated on an evapotranspiration (ET) watering schedule as recommended by Irrigation Association guidelines. When adjustments in the watering schedule are needed, these should be done monthly based on historical ET rates.

Some native and very-low-water-use plants may be weaned off irrigation over time, especially if they have been planted in water-harvesting swales or water catchments. This process should be carried out very slowly. Careful monitoring is necessary to delay irrigation until the maximum allowable depletion of soil moisture has occurred. This will vary based on soil type and the depth of the root system. Plants with shallow root zones will likely wilt more rapidly than those with deeper root zones.

It also may be possible to reduce irrigation to higher-water-use plants by watering less frequently but longer to encourage deeper root growth. It is important, however, to consider the soil type; faster draining, sandy soils will require more frequent watering than those with higher clay content. Extra care should be taken when reducing or eliminating irrigation to trees. Even native, drought-tolerant trees will require some supplemental irrigation in times of drought. Trees may take several years to die and regular observation to monitor for change is the best method for determining when a plant is experiencing stress.

Large shrubs and trees require that the irrigation zone be expanded as the roots and canopy reach farther and farther out from the original placement of the water source as illustrated in the graphics below. As this occurs, additional bubblers or drip emitters should be moved or added at the drip line of the tree. Figure 85 demonstrates the evolution of a bubbler system to accommodate increasing plant size. Figure 86 shows modification of drip emitters over time to account for plant growth.

An efficient landscape irrigation system should have a watering schedule that delivers the proper amount of water for the root depth of the plants. Over-watering wastes water by allowing it to infiltrate to below or beyond the root zone, where the plant cannot access the water. Under-watering causes plants to develop shallow, more fragile root systems that inhibit robust growth and long-term plant health. Use a soil probe to check irrigation penetration depth. Push the probe into the ground as far as it will go easily and mark the surface grade level on the probe. Pull it out and measure to determine how deeply water has penetrated the soil.

Moisture Probe Depth Chart				
Plant Type	**Root Zone Depth (in inches)**	**Depth of Probe**		
		Water	**Wait to Water**	**Overwatered**
Groundcover / turf	6-12"	0-4"	4-12"	>12"
Shrub	12-24"	0-4"	4-18"	>24"
Tree	18-36"	0-4"	4-36"	>36"

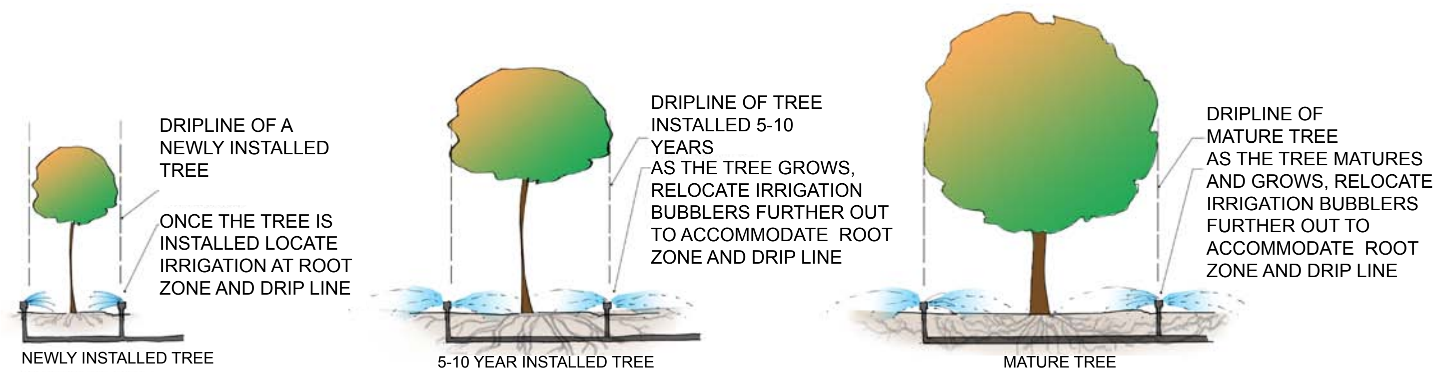


Figure 85. Bubbler Placement Modification Over Time

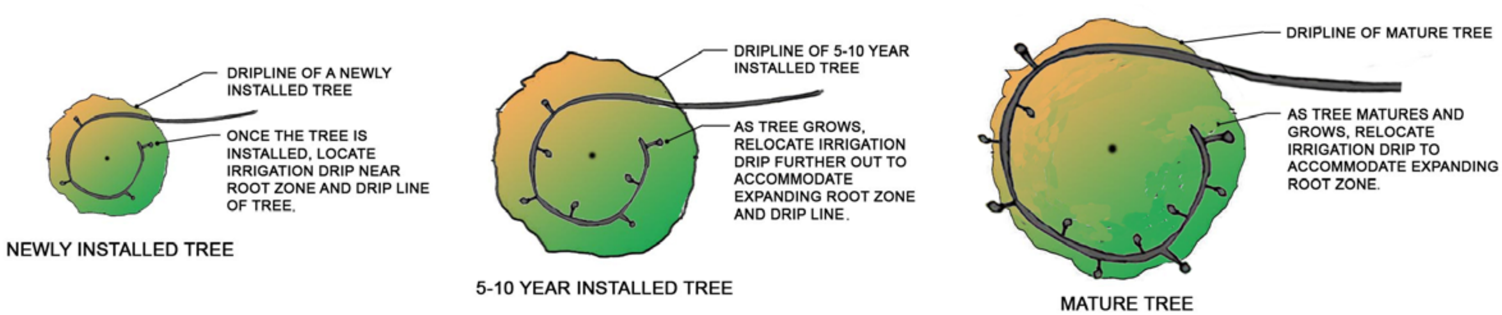


Figure 86. Drip Emitter Placement Modification Over Time

For all plantings, water slowly, deeply and less often. Drip irrigation can achieve this automatically by applying water slowly and directly to the soil. Establishing an evapotranspiration (ET) watering schedule based on Irrigation Association guidelines will help to ensure that irrigation is applied at appropriate levels.

Irrigation frequency and duration should take into account both the needs of the plant species in the landscape as well as the soil type. Sandy soils drain rapidly, whereas clay soils hold moisture for longer periods. Soils around newly constructed buildings are often compacted which also inhibits moisture penetration. Make sure that water is penetrating to the appropriate root zone depth for each plant type and do not water again until it is needed.

Watch for signs or over- or under-watering and adjust the irrigation schedule accordingly. Over-watering can cause root rot, which can be indicated by dried green leaves on the plant. Soil that is consistently damp or has mushrooms or other fungus growth can also indicate excessive irrigation. The appearance of tree roots running on top of or near the soil surface can indicate watering that is too shallow.

- ***Turf Grass Irrigation***

  Wherever possible, it is best to choose low-water-use plants or turf grass. Turfgrasses typically employed for lawns and landscaping in Bernalillo County are either cool season or warm season grasses. Cool season grasses include Bluegrasses (Poa species) and its cultivars, and many varieties of Tall-Type Fescue (festuca species). These grasses generally grow in the cooler months of the year typically in March/April and September/October; they are dormant in the winter and in the summer. However irrigation of these grasses should continue in the summer months as they are not drought tolerant grasses. Warm season turfgrasses include Bermuda (cynodon species), buffalograss (Bouteloua syn. Buchloe dactyloides), and sometimes Grama Grass (Bouteloua gracilis) or others. These grasses generally grow from April/May through August/September. During the summer months it is important that they be irrigated; however they are generally more able to withstand the heat with less water than cool season grasses and can therefore be categorized as drought tolerant grasses. Grama grass for instance should need very little irrigation once established in all of Bernalillo County; buffalograss on the other hand will require some irrigation in the West Mesa, Rio Grande Valley and East Mesa bioregions. When turf grass is used be sure to:

  - Let the grass grow taller (to 3 inches) to promote water retention in the soil. The longer grass blades make the grass more water-efficient by shading the root zone and promoting deeper root growth.
  - Follow the Bernalillo County Water Conservation Ordinance regarding turf areas sizes and do not plant turf grass areas that are less than 10 feet wide in any dimension, as they are extremely difficult to water efficiently.
  - Water turf grass areas in the evening or early morning to avoid evaporation losses.
  - Do not operate sprinklers when it is windy or raining
  - Install and maintain sprinkler head heights per the manufacturer's recommendation to avoid water waste from spray being blocked by plants.
  - Aerate turf grass areas and de-thatch to allow for proper infiltration of irrigation water. Photo 75 shows turf grass thatch. Thatch is the fibrous area between the soil and the grass.
  - Water only when necessary, generally every three or four days. Watering less frequently promotes deeper root growth which increases the lawn's water efficiency. It takes 660 gallons of water to supply 1,000 square feet of lawn with one inch of water.
    - A good way to check whether turf needs watering is to step on the grass. If it springs back up when you move, it doesn't need water. If it remains flat, watering is appropriate.

Photo 75. Turf grass thatch

- ***Irrigating Trees***
  - Provide gaps in the watering schedule to allow soils to dry. This permits needed aeration for tree roots.
  - Proper irrigation will promote tree health and make trees less prone to insect damage and disease. The depth of soil infiltration after watering should be checked to verify that trees are not being under- or over-watered. Deeper irrigation encourages deeper root growth, and deeper roots are less apt to be stressed by higher soil temperatures closer to the surface.

- ***Irrigating on Slopes***
  - Place bubblers on the uphill side of plants. See Figure 87 for an example of this type of installation.
  - Construct a watering well around the base of the plant or plant group to hold and allow irrigation water to infiltrate the plant root zone.
  - Program your controller to irrigate slopes over several cycles, allowing water to infiltrate while preventing excess runoff.

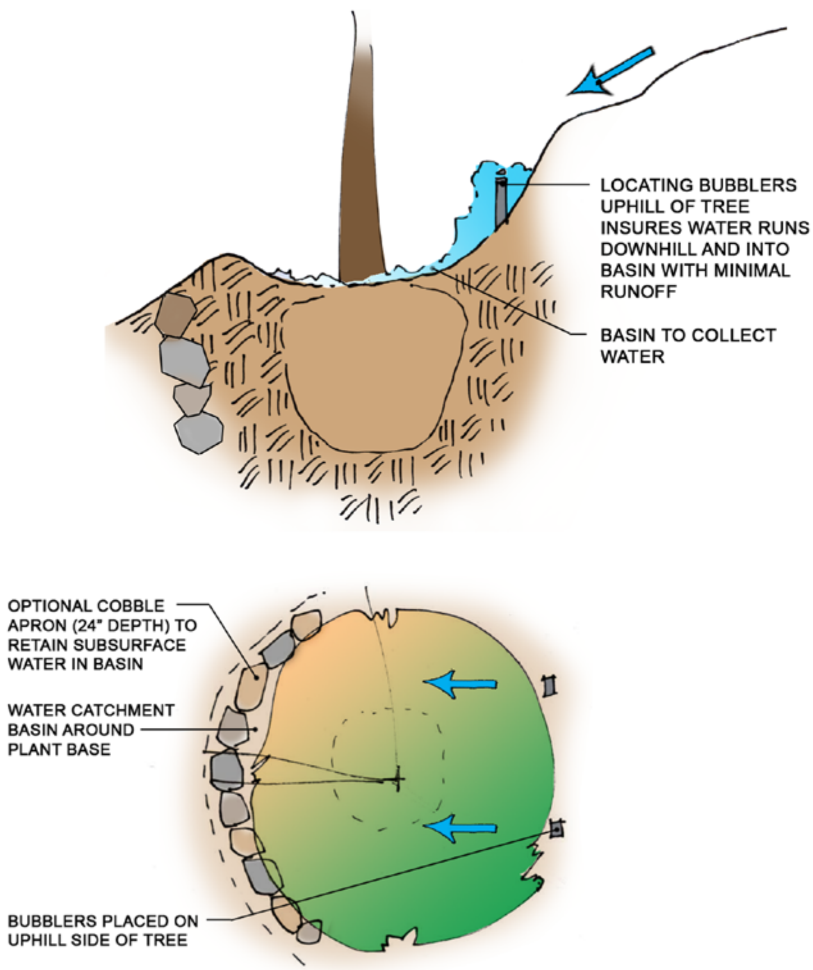


Figure 87. Bubbler Placement on Slopes

Best Management Practices for Irrigation System Maintenance

Commercial irrigation systems should be inspected, adjusted and repaired on a monthly basis. Inspection should include adjusting valves, heads, checking nozzles and verifying the operation of sensors. Drip irrigation filters and emitters should also be checked monthly and cleaned or replaced as needed. Turn on the irrigation system and visually make sure that all emitters are operating properly.

An annual water audit should be performed to check the system's efficiency and determine if modification to the irrigation water schedule is needed. The following issues are typically checked during an irrigation system audit and provide a good initial starting point for improving water efficiency:

- Improper operating pressure – Operating at the wrong pressure causes the system to operate inefficiently, wasting water and potentially damaging equipment.
- Tilted sprinkler heads (should be straightened).
- Broken heads or pipes.
- Obstructed spray patterns.
- Low head drainage – The loss of the water that remains in the pipe after the system turns off. Gravity will cause the water to flow through the pipe to the lowest point, where it leaks in to the landscape. By using sprinklers with built-in check valves, this water will be retained within the pipe and not lost as excess water in the landscape.
- Clogged nozzles or emitters.
- Improperly mixed equipment - Never mix different types, brands or models of sprinklers or different nozzles on the same irrigation zone as this will contribute to water loss from inefficiencies.
- Sprinklers not installed at the proper height - Sunken sprinklers often will not pop up high enough to spray over the height of the grass, disrupting the proper spray pattern of the water. Figure 50 shows an example of this.
- Improper arc adjustment of sprinkler heads
- Rotary heads that no longer rotate.
- Use of non-pressure-compensating emitters.
- Leaking pipes and equipment.
- Compaction and excessive turf thatch.
- Backflow prevention devices - inspect periodically, at a minimum as determined by local ordinance.
- Hidden leaks - use your water meter to check for hidden leaks. Read the meter at the beginning and end of a two-hour period when no water is being used in the house or landscape. If the meter reading isn't exactly the same, there is a leak somewhere in the system.
    - Check for leaks in hose bibs as they can lose more than 73 gallons per day depending on the size of the leak.
- Freeze damage - winterize systems in areas where freeze damage is a real threat. In warmer areas, the system should be maintained and operated to compensate for typical winter drought times.

Additional information on designing and installing irrigation systems, designers, and irrigation technologies is available through the websites listed below.

EPA
http://www.epa.gov/watersense/docs/home_draft_spec508.pdf
Information and resources for commercial and institutional water users

Bureau of Reclamation- Smart technology
http://www.usbr.gov/waterconservation/docs/SmartController.pdf

Irrigation Association Turf and Landscape Irrigation Best Management Practices
http://www.irrigation.org/Resources/Turf___Landscape_BMPs.aspx

Hiring a Professional
http://www.irrigation.org/hirecertified/
http://findalandscapepro.pbwiki.com/How+to+Hire+a+Pro

Hunter Irrigation Homeowner's Irrigation Information
http://www.hunterindustries.com/homeowners.html

Toro Homeowner's Irrigation Information
http://www.toro.com/sprinklers/guides.html

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Horticulture www.hortmag.com
Organic Gardening www.organicgardening.com
Sunset Magazine www.sunset.com

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Forgotten Rain, *Rediscovering Rainwater Harvesting,* Heather Kinkade-Levario, 2003
www.forgottenrain.com

Suzy Banks & Richard Heinichen, *Rainwater Collection for the Mechanically Challenged*,

Brad Lancaster, *Rainwater Harvesting for Drylands*, . www.harvestingrainwater.com

Stormwater as a Resource, How to Harvest and Protect a Dryland Treasure
http://www.nmenv.state.nm.us/swqb/Storm_Water_as_a_Resource.pdf

Wendy Price Todd & Gail Vittori. T*exas Guide to Rainwater Harvesting., 2nd Ed.*
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